



PAPERS AND PROCEEDINGS OF

THE

ROYAL

SOCIETY

OF TASMANIA



Edited by M. R. Banks and S. J. Smith

and Published by the Society

Hobart

Tasmania

31 AUGUST 1993

VOLUME 127





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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA VOLUME 127

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ROYAL SOCIETY OF TASMANIA

Annual Report for the Year 1992

The Council has the honour to present to members the following report on the activities of the society during the year.

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Dr M.R. Banks AM

Honorary Assistant Editor
Dr S.J. Smith

President

His Excellency General Sir Phillip Bennett took the chair as President of the Society at the Annual General Meeting and at the August Meeting of the Northern Branch. He also attended a meeting in August in the Town Hall held as a part of the City of Hobart's 150th Anniversary.

Deaths

The deaths of the following members are recorded with regret:

Mr V. Walmsley
Mr C.H. Grant
Mr L.E. Couchman
Dr W. Bryden
Miss M.B. Record

William Bryden, CBE, DSc, PhD, FRS Edin, FGA (1904–1992)

Dr William Bryden died at Buderim, Queensland on 16 December 1992 just two weeks before his 88th birthday.

Dr Bryden was Honorary Secretary, Honorary Librarian and Honorary Editor of the Society from 1953 to 1972. He was elected an Honorary Life member in 1971 and awarded the Clive Lord Memorial Medal in 1973. He served on the Council from 1953 to 1971 and from 1973 to 1977. He was Vice-President from 1973 to 1975 and Honorary Treasurer for 1977.

Dr Bryden was born in New Zealand and studied for his first degrees in botany and zoology at Canterbury University College (now the University of Canterbury) in Christchurch. His PhD on animal behaviour and genetics was from the University of Edinburgh, where he played rugby union for the University. He was on the staff of the University of Melbourne from 1935 to 1940. From 1940 to 1953 he was Headmaster of Knox Grammar School, Sydney.

In 1953 he was appointed Director of the Tasmanian Museum and Art Gallery. He retired from that position in early 1972, at which time he was awarded an honorary DSc by the University of Tasmania. He served in many positions in Tasmania, including Chairman of the National Parks and Wildlife Advisory Council, Trustee of the Van Diemen's Land Memorial Folk Museum and President of the Hobart Repertory Theatre. He was for 10 years a member of the University of Tasmania Council and for 12 years on the State Committee for CSIRO. In 1967 he tragically lost his home at Kingston, together with all his possessions, in the bush fires.

In 1983 Dr Bryden and his wife Muriel shifted from Tasmania to Buderim. He is survived by his wife and his sons Peter, Michael and John.

Membership

The membership is 411, a decrease of 11, and is made up as follows:

	Northern	Total
Honorary Life Members	2	7
Life Members	11	34
Ordinary members receiving <i>Papers and Proceedings</i>	54	256
Ordinary Members not receiving <i>Papers and Proceedings</i>	41	97
Associate Members	<u>2</u>	<u>17</u>
	117	411

Council Meetings

The Council met four times during the year,

Sesquicentennial of the Society

The Society's sesquicentennial in 1993 will be marked in a number of ways, the most tangible being by the publication of James Backhouse Walker's *Walk to the West* (1887). Donations from learned Societies around the world, the Australian business community, the Federal and State Governments, the City of Hobart and the University of Tasmania, together with advance orders for over 300 copies have assured the financial viability of the project. The book will be launched in March 1993.

Grants to the Society

The Council received grants from the Tasmanian Government and from the University of Tasmania each of \$3000 as contributions to the publication of the *Papers and Proceedings*. A special grant of \$2570 towards the publication of *Walk to the West* was also received from the State Government.

Library

The year in review has been one of significance for the Society's Library with steady progress in the innovations

established during 1991 and some notable activities during the year.

In April the University Library and the Society established a revised agreement for the housing and maintenance of the library which, although not substantially different from the previous agreements, allows for some greater flexibility and variant treatment of the library's material. As a follow-up to this agreement, new cataloguing procedures were established later in the year which allow for the new accessions of the Library to be fully processed by the University's Cataloguing Department, and these appear as Royal Society items in the University Library catalogue. A small retrospective program will enable existing material to progressively appear in the computer catalogue, but a more comprehensive re-cataloguing program still lies in the future. Some physical rearrangement was necessary to allow for these new sequences of catalogued material and these now appear on the first ranges of permanent shelves inside the library.

The weeding program established in 1991 was continued during the year with a second batch of outdated and superseded titles being prepared for disposal. Lists of such items will be distributed to members who will have first claim on items being withdrawn.

Another feature for the year was the continuity in staffing, with Graeme Rayner continuing in the position of Collection Development Librarian, which incorporates Special Collections and hence the Royal Society Library. Clerical assistance was maintained by Mrs Carol Freeman who continued to spend the major part of her 20-hour week on Royal Society routines.

Two further issues of the Society's *Papers and Proceedings* were distributed to exchange partners during the year. Volumes 125 and 126 were both mailed without problems, in February and December respectively.

As stated in last year's report, user statistics remain a problem as a number of users omit to sign the visitors and usage registers. Whilst every attempt has been made to encourage such registration the recorded statistics are still somewhat lower than reality:

Visitors	384
Serial Loans	48
Inter-Library Loans	37
In-house consultations	141
Volumes bound	163

By far the most significant event for 1992 was the receipt of a substantial donation from the estate of the late Len Couchman, embracing, amongst some general material, a number of entomology titles (on lepidoptera especially). The donation, which involved over 200 titles and several serial runs, has been temporarily housed on additional shelving in the Library and, as of December, has been completely checked against the Library's existing holdings. Cataloguing of the titles has begun and a particularly suitable bookplate displaying one of four different Tasmanian butterflies will be inserted in each title added to the collection. Inevitably with such large donations of this nature, some titles will be duplicates or otherwise unsuitable for the Library and these will be listed for disposal to members of the Society in the first instance.

Overall, the year has been one of considerable achievement for the Library, one in which a number of significant changes took place and in which the Library's unique resources were of considerable help to a number of researchers who visited during the year. It is these unique and valuable resources

which should see greater exploitation, once they are listed in the more widely distributed catalogue of the University Library, and thus assist the promotion of the Society and its ideals.

Publications

Volume 126 of the *Papers and Proceedings* was published in November. It contained the Annual Report for 1991, 17 papers by 23 authors and an erratum. The Annual Report occupied five pages, the papers 125.

Publication of the papers given at the WHA Symposium proceeded and was approaching completion by the end of the year. Printing should occur in the first half of 1993.

Publication of Volume 126 was facilitated by receipt of financial grants from the State Government of Tasmania and the University of Tasmania.

Mrs Alison Jones provided expert sub-editing, Mrs J. Pongratz the quality typesetting and formatting, Drs M. Banks and S. Smith edited the volume.

Lectures

The following lectures were given at General Meetings during the year:

- March — "World Heritage Area management and wildlife conservation in North and South America" Dr Steven Smith, Department of Parks, Wildlife and Heritage
- April — "Conservation of the Southern Elephant Seal" Dr Mark Hindell, University of Tasmania
- May — "Harmony and discord: new buildings — old cities" Mr Neil Wade, Architect
- June — "The Dutch debate over Tasman" Dr Eric Ketelaar, General State Archivist of the Netherlands
- July — "Rewriting Tasmanian history — the archaeological evidence from Tasmania's forests" Anne McConnell, Forestry Commission
- August — "Changing attitudes in cultural resource management, with reference to the Hobart Town Hall" Mr R. Vincent, Hobart City Council
- September — "Aurora and the earth's magnetic field" Dr Gary Burns, Antarctic Division
- October — "Rare bird record verification" Mr Bob Patterson, Chairman of the Rarities Appraisal Committee of the Royal Australasian Ornithologists Union
- November — "The European context of Dutch exploration in Southeast Asia" Assistant Professor Michael Bennett, University of Tasmania and "Tasman's discoveries in Tasmania and some contemporary linkages" Mr Geoff Wood, Tourism Tasmania.

Northern Branch

Branch Council

Chairman	Mrs Mary Cameron
Past Chairman	Mr A. Orr
Honorary Secretary	Mr C. Tassell
Honorary Treasurer	Mr B. Pike
Council Members	Mr B. Chamberlain
	Mr J. Kolkert

The Branch Council met four times during the year.

Meetings and Lectures

- March — Annual General Meeting and "History and the future of the HEC" Mr G.J. Longbottom
- April — "The telegraph semaphore signal system in the Tamar River valley" Mr W. Shipp
- June — "The history of the Lisle goldfields" Mr C. Cornoneos
- August — "United States then Australia" Professor J. Harvey Prince. This meeting was chaired by H.E. the Governor of Tasmania, General Sir Phillip Bennett.
- September — "What the community history collection is about" Mrs Rhonda Hamilton
- October — "Snakes on Mt Chappell Island" Mr I. Norton
- November — "Reminiscence of activities over 50 years" Mr B. Farquhar
- December — Members Night.
"Looking up" Mr A. Orr
"Children in Launceston in 1890s" Mrs G. Morris
"Tankers" Mr J. Kolkert.

Excursion

On 11 April an excursion to Mt Direction, Mt George and Low Head was led by Mr W. Shipp.

Nominees to Other Bodies

The Council elected Dr P.G. Quilty and Professor D.M. Stoddart to serve on the Board of Trustees of the Tasmanian Museum and Art Gallery. They report on the year's activities:

1992 was a year of consolidation for the Tasmanian Museum and Art Gallery. Discussions with the Department of Education and the Arts on restructuring took place during much of the year, with an agreed plan being submitted to the Department in December. The Department of Construction continued its audit of space and of the whole Museum and Art gallery precinct. The Trustees took a number of opportunities to press the Federal Government for a clear decision on the fate of the Customs House but to date no clear progress has been made.

The 1991 State Budget provided a grant for recurrent services of \$1 564 000, an increase of 0.77% over the allocation in 1990. Of this, 79.9% will be expended on salaries.

During the year Dr Tony Orchard resigned his position as Curator of Botany and Head of the Herbarium. To date the post remains unfilled. Dr Gintaras Kantvilas was appointed Acting Head of the Herbarium.

In the early part of the year the Museum and Art Gallery took delivery of three personal computers and two printers and embarked on the computerisation of all its records.

Towards the end of 1992 the Tasmanian Museum and Gallery staged its most ambitious art exhibition, with a retrospective of over 100 of W.C. Piguenit's works. In opening the exhibition, the Lt Governor, Sir Guy Green, spoke with pride of the work of Tasmania's greatest landscape artist. This exhibition will be shown in Sydney and Perth in 1993.

Other exhibitions in 1992 included the *Moet and Chandon* touring exhibition (February–March); *Interpretations: The Woven language of the Victorian Tapestry Workshop* (March–April); *17th Century Dutch Etchings by Cornelius Bega and Adriaen van Ostade — an Abel Tasman Festival Exhibition*

(May–June); *Australian Watercolours 1802–1926* — from the collection of the National Gallery of Victoria (June–July); *Francis Lyburner Retrospective* (July–September); *Printworks by Japanese Contemporary Artists* (October–November); *The Work of Francis and Anna Maria Nixon* (October–November); and *W.C. Piquenit Retrospective* (December–February).

During 1992 a total of 97 952 people visited the Museum and Art Gallery, compared with 99 517 in 1991. The number of visitors to the West Coast Pioneers' Memorial Museum in Zeehan was estimated at about 96 000 for 1992, approximately the same as in 1991.

Mr J.E. Tomlinson AO was elected by the Council to serve on the Board of Trustees of the Royal Tasmanian Botanical Gardens. Mr Tomlinson reports on the year's activities:

The year was marred by the untimely death in February of Mr Tony May who had been superintendent of the gardens for 16 years. Many developments are a living memorial of his work.

In August, after many years as Chairman of Trustees, Mr Grey Hulton AM, decided it was time to "hang up the boots". He has been replaced by Mr Rod Moore.

Alderman G. Yeoland retired from the Trustees and was replaced by Ald. D. Haigh as the Hobart City Council's representative.

Finance has continued to be the major constraint and at the time of writing the 1992–93 allocation has not been finalised. However, the new irrigation system was opened in October by John Cleary MHA, Minister for Parks, Wildlife and Heritage, and during the year a new roof was put on the conservatory.

The Gardens were well used, with 324 000 visitors for the year to June, which was 40 000 up on the previous year.

The Tulip Festival attracted some 15 000 visitors. Zootango Theatre Company staged *A Midsummer Night's Dream* in the gardens in January and *Alice in Wonderland* in December. These events have been a success not only in bringing people to the Gardens but also assisting the Gardens financially.

The Friends of the Gardens have continued to assist both financially and by acting as volunteer guides and bus drivers for the elderly and incapacitated.

Two staff were able to travel overseas at no cost to the Gardens. Mr Andrew Smith, the Education Officer, was invited by the Botanic Gardens Conservation International to deliver a paper on *Conservation Education in Botanic Gardens* at a conference in Rio de Janeiro and Mr Jim Cane, the Acting Superintendent, went to China on a seed collection trip. Both of these will be of benefit to their work in the Gardens.

Acknowledgements

The Council is grateful for help generously given by many individuals and organisations. In particular, the lecturers, the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, and the Queen Victoria Museum and Art Gallery are specially thanked for their help and cooperation.

We are grateful for the dedicated help given by members of the Council during the year.

A.V. Brown
Senior Vice-President

D.M. Stoddart
Acting Honorary Secretary

February 1993

ROYAL SOCIETY OF TASMANIA

Statement of receipts and payments for the year ending 31 December 1992

General Account

Balance 1 January 1992	22 276.53	Printing and stationery	1 479.65
Subscriptions		Postage	771.88
216 @ \$30	6465.00	Post box rental	180.00
80 @ \$18	1440.00	Library books & subs	1 480.18
16 @ \$12	192.00	Telephone	30.47
Other years	<u>654.00</u>	Bank duties and charges	55.62
	8 751.00	Attendant fees	665.98
Publication sales	4 130.48	Northern Branch	750.00
Interest	2 290.57	Insurance	421.33
Interest - other	75.75	Sundry	40.70
Investments redeemed	2 000.00	<i>Papers & Proceedings</i>	6 341.75
<i>Walk to the West</i>		<i>Walk to the West</i>	
Donations	12 157.03	Flyers	715.00
Advance sales	23 435.00	Sundry	<u>440.68</u>
Post & packing	<u>540.00</u>	Lecture fees	567.20
	<u>36 132.03</u>		13 940.44
		Balance 31 December 92	<u>61 715.92</u>
	<u>\$75 656.36</u>		<u>\$75 656.36</u>

ROYAL SOCIETY OF TASMANIA
Statement of receipts and payments for the year ending 31 December 1992

Accumulation account

Balance 1 January 1992		59 699.76
<i>Add</i>	Increased cash at bank	<u>39 638.39</u>
		99 338.15
<i>Deduct</i>	Net increase in advance subscriptions	74.00
	Decreased valuation of publications	562.90
	Net transfer to Trust Funds	537.57
	Decreased investments in stocks and bonds	<u>2000.00</u>
		<u>3 174.47</u>
Balance 31 December 1992		<u>\$96 163.68</u>

Balance sheet as at 31 December 1992

1991		1992
59 700	Accumulated Funds	96 163.68
52	Subscriptions in advance	126.00
	Trust Funds:	
2 250	– Clive Lord Memorial Fund	2 295.50
4 780	– A.N. Lewis Memorial Fund	4 875.83
2 270	– Morton Allport Memorial	2 315.64
869	– A.A. Clark Bequest	885.91
2 424	– Joseph Milligan Bequest	2 472.81
3 233	– R.M. Johnston Memorial Fund	3 298.04
1 333	– Henry Oliver Bequest	1 359.29
3 114	– W.H. Hudspeth Memorial	3 175.78
<u>6 606</u>	– Life Membership Fund	<u>6 737.66</u>
<u>\$86 631</u>		<u>27 416.46</u>
		<u>\$123 706.14</u>

Represented by:

33	Cash on hand	33.00
	Cash at bank:	
22 276	– General account	61 715.92
4 743	– <i>Papers and Proceedings</i> account	4 888.51
1 060	– Clive Lord Memorial Fund	1 078.89
1 491	– A.N. Lewis Memorial Fund	<u>1 525.12</u>
860	Mortgage Loan	69 208.44
2 000		860.00
	Commonwealth Treasury Bonds and	
	Inscribed Stock (at cost)	
7 000	Interest bearing deposits	7 000.00
15 000	Library (at valuation for insurance)	15 000.00
26 568	Publications (at selling prices)	26 004.70
<u>5 600</u>	Medals (at selling price)	<u>5 600.00</u>
<u>\$86 631</u>		<u>\$123 706.14</u>

The Society owns works of art which have been donated over the years and which do not appear on the Balance Sheet. They are all housed in the Tasmanian Museum and Art Gallery and are covered by that organisation's insurance. A catalogue is available to members listing these works of art.

D.M. Stoddart
A/Honorary Secretary

T.A.H. Knight, B.Bus. CPA
Honorary Treasurer

SPARTINA ANGLICA COLONISATION AND PHYSICAL EFFECTS IN THE TAMAR ESTUARY, TASMANIA 1971–91

by Ada W. Pringle (née Phillips)

(with three tables and eight text-figures)

PRINGLE, A.W., 1993 (31:viii): *Spartina anglica* colonisation and physical effects in the Tamar estuary, Tasmania 1971–91. *Pap. Proc. R. Soc. Tasm.* 127: 1–10. ISSN 0080–4703. Department of Geography, Lancaster University, Lancaster LA1 4YB, UK.

The extent, form and condition of *Spartina anglica* in the Tamar Estuary changed between the summer of 1971/72 and 1991, probably due to differences in maturity and substrate. This exotic saltmarsh grass stabilised and raised the intertidal mudflats and constrained channel movements, but it has also reduced recreational facilities and its spread is largely uncontrollable.

Key Words: *Spartina*, saltmarsh, estuary, Tasmania.

INTRODUCTION

The main characteristics of the Tamar Estuary (fig. 1) were formed when a rise in sea level of approximately 60 m, between about 13 000 and 6500 yrs BP, drowned the pre-existing river valley (Thom & Roy 1985). The 61 km long estuary, extending between Launceston and Low Head on Tasmania's Bass Strait coast, follows a winding course of variable width, with wider basins separated by narrower reaches. A single major navigable channel is flanked by broad intertidal mudflats in the basins, although these become narrow or absent in the constricted reaches.

It was into these mudflats at Windermere that *Spartina anglica* was first introduced in 1947 (Ranwell 1967, Phillips 1975); Boston (1981) provided further details. Plants from Buckland Park, South Australia, were obtained for the Marine Board of Launceston by the Tasmanian Department of Agriculture. The original planting at Buckland, in the intertidal zone of the Gawler River, was in January 1931; the plants were sent from England (by E. V. Oliver of University College, London, and R. Cartridge of Poole Harbour, Dorset) to the Department of Agriculture, Adelaide. As recorded by Martin (1971), an agronomist with the Tasmanian Department of Agriculture, Launceston, *Spartina* was introduced to the Tamar in an attempt to

stabilise the mud flats so that they would eventually be above high water level and become relatively useful land and in the hope that this would

force the stream flow into the central part of the river, creating a scouring effect and keeping the main channel relatively free of mud.

Additional plantings, using local material, were carried out up to 1964. During the early 1960s, *Spartina* appeared rapidly and extensively on neighbouring intertidal mudflats (Phillips 1975). The spread was achieved partly by rooting of broken fragments distributed by tidal currents and also by seeding (a 15% germination rate was proved by the Department of Agriculture). By the summer of 1971/72, *Spartina* covered over 500 ha (fig. 2) in a 29 km stretch of the central Tamar between Dilston–Dog Point upstream and East Arm–Ruffins Bay downstream (Pringle 1975).

SPARTINA SURVEYS SINCE 1971/72 SUMMER

Following the detailed field investigations of 1971/72, more limited surveys have been undertaken during short return visits to Tasmania. Tidal relationships of the *Spartina* marsh were investigated in 1977 (Pringle 1982). The extent and form of *Spartina* colonisation in the Tamar Estuary were mapped in the field in August 1983, April–May 1988 and September–October 1991, and were plotted on 1:72 000 base maps, as used also in the 1971/72 field survey. Areas on the intertidal mudflats with continuous *Spartina* sward were distinguished from those containing separate rounded clumps and isolated shoots, as in the earlier field survey. Mapping was carried out from the shore mainly, but the marsh was inspected also from the river, enabling more inaccessible shores to be mapped. When aerial surveys (table 1) had been carried out near to the dates of the field surveys, the photographs were used to cross-check with the field mapping. These were especially important for establishing the limits and form of the most extensive area of

TABLE 1.
Aerial surveys used in this study

Date/project	Scale	Remarks
22.12.74 1976 census, Launceston	1:40 000	Mid-tide to HW, some saltmarsh visible
19.1.83 & 13.2.83 M263 Tamar Valley	1:15 000	Mid-tide, much saltmarsh visible
29.10.84 M492 Tamar Valley	1:15 000	Timed across LW at Rosevears, all saltmarsh visible
17.12.87 M169 Tamar Valley OPM	1 28 000	About LW at Rosevears, all saltmarsh visible
2.2.91 M919 Upper Tamar	1:15 000	About LW, all saltmarsh visible

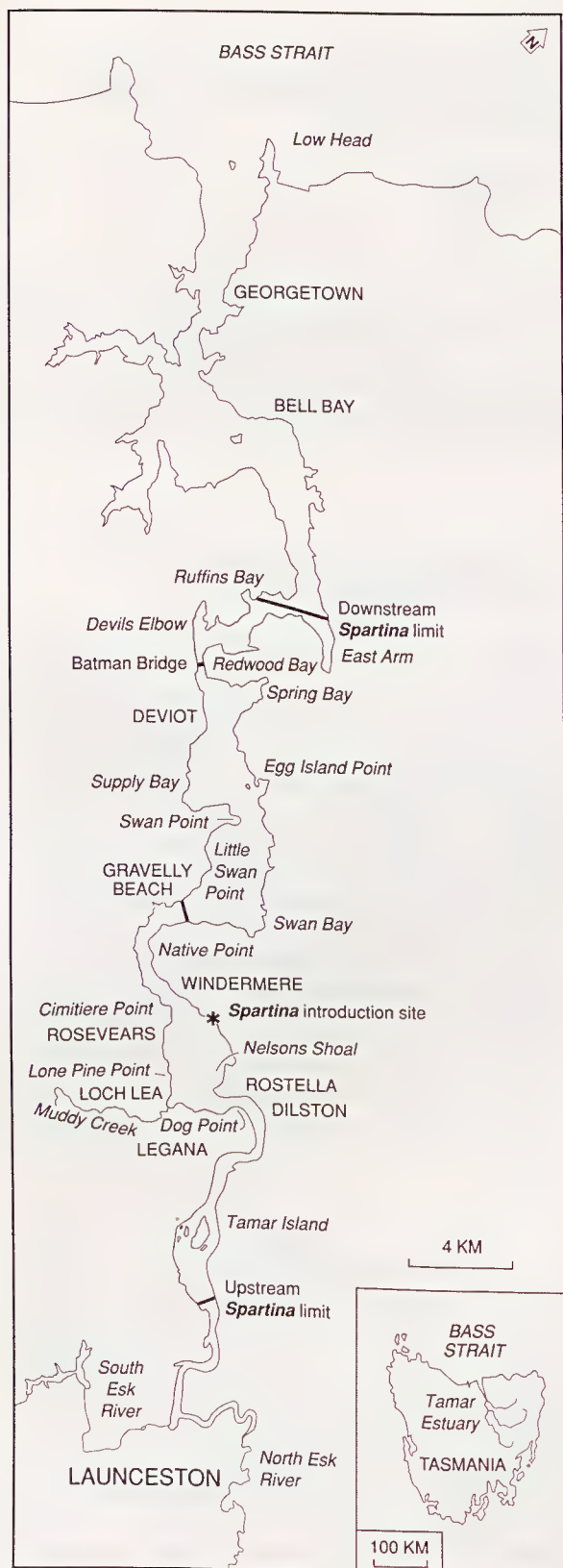


FIG. 1 — Location map of Tamar Estuary.

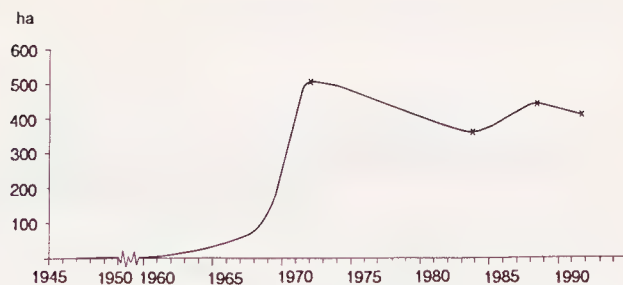


FIG. 2 — Area of *Spartina anglica* in Tamar Estuary 1947/91. Based on aerial surveys, except 1971/72, and field surveys (x) from 1971/72 onwards.

Spartina marsh on Nelsons Shoal. A colour aerial survey, at 1:15 000, flown about low water (LW) on 2 February 1991, covered the whole stretch of the Tamar Estuary where *Spartina* is colonising (except for East Arm and part of Ruffins Bay); this was particularly valuable for the 1991 field survey.

In addition to the general field mapping of the *Spartina* marsh, replicate cross-profile surveys have been carried out, using an automatic level. A transect line established between high and low water marks (HWM and LWM) at Rosevears (fig. 1) in January 1972 was resurveyed in August 1977, August 1983, April 1988 and September 1991. New transect lines were established in collaboration with the Port of Launceston Authority (PLA) in August 1983 at Windermere and Swan Bay (fig. 1). In addition to surveys of them by the author in August 1983, April 1988 and October 1991, these cross-profiles and that at Rosevears were surveyed by the PLA in August each year between 1984 and 1989. (Full records are kept by the PLA.)

As well as the Tamar Estuary *Spartina* survey in 1988, a general inspection and survey was made of *Spartina* colonisation in other Tasmanian Bass Strait estuaries (Pringle 1988), into which plants from the Tamar had been introduced between 1949 and 1974 (Boston 1981).

OVERALL EXTENT OF SPARTINA MARSH

The area calculations for *Spartina* in the Tamar Estuary (fig. 2) were based on aerial surveys alone up to 1970. As noted earlier (Phillips 1975), for *Spartina* to be recognised on these aerial photographs, which ranged in scale between 1:51 480 and 1:6336, it must be growing densely, in either a continuous sward or closely spaced clumps. The detailed field survey of 1971/72 enabled the distribution of isolated shoots also to be mapped; therefore the total areal extent (555 ha) of *Spartina* for that summer is not strictly comparable with the earlier calculations. In addition, it appears from later aerial surveys that there was an overestimation of the area of *Spartina* on the Nelsons Shoal mudflats in 1971/72. (Facilities had not been available then for a detailed instrumental ground survey of this treacherous intertidal area.) By making due allowance for both these factors, it appears that an area of 512 ha is more closely comparable with the calculations for earlier years.

The more general field surveys carried out in 1983, 1988 and 1991 enabled areas of sward, clumps and isolated shoots to be mapped, although the shoots were those growing in close proximity to the clumps rather than alone along a shoreline, as mapped in places in 1971/72. As indicated above, *Spartina* distribution was checked on aerial photo-

graphs (table 1), where these were available for dates near those of the ground surveys. The area calculations are, therefore, comparable with those for earlier years.

The explosive nature of the *Spartina* colonisation in the Tamar Estuary between the summers of 1968/69 and 1970/1971, after slower initial establishment between 1947 and 1968 (fig. 2), was considered earlier (Phillips 1975). The intertidal mudflats provided a vacant niche, which previously had been colonised only by the algae *Enteromorpha*. Near HWM limited saltmarsh had developed, with *Sarcocornia quinqueflora* as the main primary coloniser and the rear of the marsh dominated by *Phragmites*, *Juncus* and *Gahnia*. The sudden rapid expansion of *Spartina* into this vacant niche was probably the result of an unusually good year(s) for seedling establishment, following an infrequent episode of considerable seed production. Similar rapid bursts of colonisation have been noted in several British estuaries; the Conway Estuary in North Wales (Gray *et al.* 1990), Morecambe Bay, northwestern England (Whiteside 1987) and Cromarty Firth, Scotland (Smith 1982). Marks & Mullins (1990) investigated seed production in a range of English *Spartina* marshes, and concluded that tidal range, date of inflorescence emergence, soil temperature and salinity were all important influencing factors. Gray *et al.* (1990) note that it is not yet known what constitutes a good year for seedling establishment; temperature, tide-related phenomena such as mudflat elevation, and/or genetic reasons may provide an explanation.

Because of the 11-year gap between the 1971/72 and 1983 field surveys, only an overall downward trend in *Spartina* area to 367 ha can be deduced (fig. 2). This was followed by an increase in area to 447 ha in 1988 but subsequently a reduction to 412 ha in 1991.

VARIATIONS IN SPARTINA DISTRIBUTION

Variations in the distribution pattern of *Spartina* colonisation were apparent during the field mapping and subsequent area calculations based on the 1:72 000 maps. In table 2, separate data for sward and for clumps and shoots are listed for the western and eastern shores of the Tamar, and also for sections of the estuary upstream and downstream from a line through Gravelly Beach (GR 979291) to the eastern shore opposite (GR 986285) (fig. 1). The upstream section extends to the shores slightly upstream of Tamar Island, although *Spartina* covers relatively small areas above Dilston on the eastern shore and Dog Point on the western shore. The downstream section extends to East Arm and Ruffins Bay. The winding nature of the Tamar Estuary, with alternating basins and narrow reaches, has already been noted. The line through Gravelly Beach divides the area where *Spartina* is colonising into an upstream basin, with narrower stretches above and below, and a larger downstream basin, leading to a narrow stretch near the downstream limit of growth.

When the areal distribution of *Spartina* is examined separately on each shore of the Tamar, during the period 1971/72 to 1991 (fig. 3, tables 2 & 3), it is immediately apparent that the area occupied on the eastern shore is over twice that on the western shore. In 1971/72, on the eastern shore the area of sward was nearly twice that of clumps and shoots, whereas on the western shore the areas were similar. By 1983, the area of sward on both shores had increased slightly, and the overall reduction shown in *Spartina* area

resulted from a pronounced fall in the area of clumps and shoots to about 9% of the total area on the eastern shore and 15% on the western shore. The overall increase in *Spartina* area between 1983 and 1988 was brought about by an increase in sward area on both shores whilst a slower reduction in area of clumps and shoots occurred. The slight reduction in total *Spartina* area between 1988 and 1991 reflects a similar reduction in area of sward on both shores, combined with a continued slow reduction in area of clumps and shoots on the eastern shore although there was a slight increase on the western shore.

When the areal distribution of *Spartina* is considered upstream of Gravelly Beach, it is clear that nearly twice the area is colonised, as compared with downstream, and other differences also emerge during the 20-year period (Fig. 4, tables 2 & 3). In 1971/72, in the upstream section 86% of

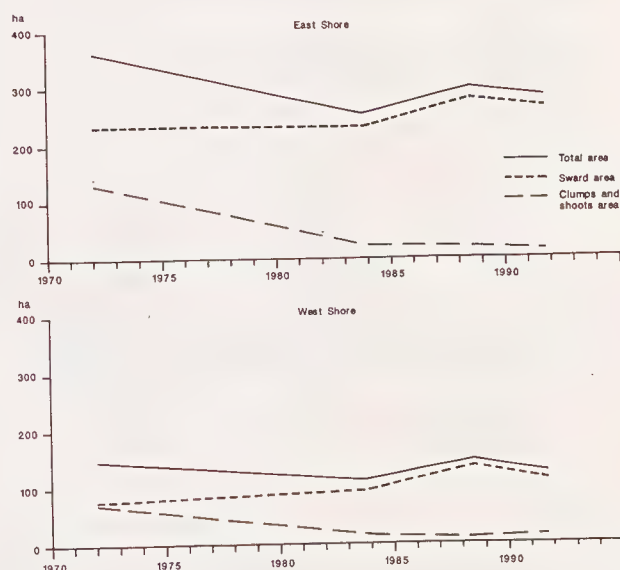


FIG. 3 — Area of *Spartina anglica* on eastern and western shores of Tamar Estuary, 1971/72 to 1991.

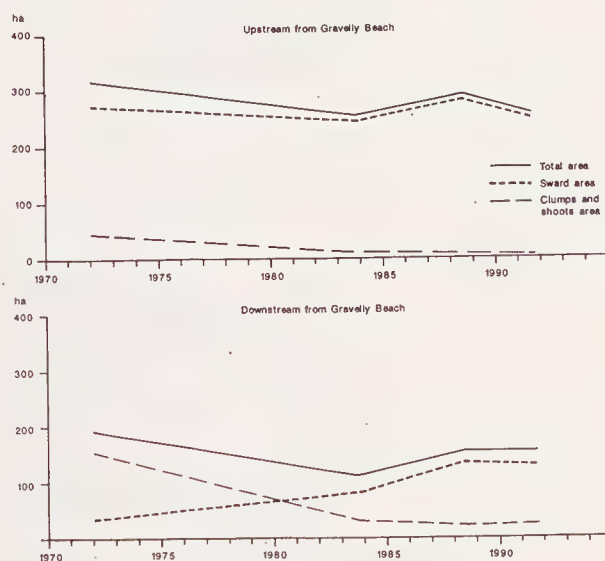


FIG. 4 — Area of *Spartina anglica* upstream and downstream from line through Gravelly Beach, Tamar Estuary 1971/72 to 1991 (see fig. 1).

TABLE 2
Area of *Spartina anglica* in the Tamar Estuary (ha)

Estuary section	Western shore			Eastern shore			Total		
	Sward	Clumps & shoots	Total	Sward	Clumps & shoots	Total	Sward	Clumps & shoots	Overall
<i>November 1971/January 1972</i>									
Upstream *	63.38	16.50	79.88	210.38	28.63	239.01	273.76	45.13	318.89
Downstream †	13.25	55.63	68.88	22.25	101.88	124.13	35.50	157.51	193.01
Total	76.63	72.13	148.76	232.63	130.51	363.14	309.26	202.64	511.90
<i>August 1983</i>									
Upstream	66.25	4.50	70.75	178.25	5.75	184.00	244.50	10.25	254.75
Downstream	28.13	12.63	40.76	53.25	18.25	71.50	81.38	30.88	112.26
Total	94.38	17.13	111.51	231.50	24.00	255.50	325.88	41.13	367.01
<i>April–May 1988</i>									
Upstream	89.38	2.00	91.38	192.38	6.75	199.13	281.76	8.75	290.51
Downstream	48.13	8.00	56.13	87.38	13.38	100.76	135.51	21.38	156.89
Total	137.51	10.00	147.51	279.76	20.13	299.89	417.27	30.13	447.40
<i>September–October 1991</i>									
Upstream	67.50	1.13	68.63	180.38	5.63	186.01	247.88	6.76	254.64
Downstream	44.63	14.88	59.51	85.88	11.63	97.51	130.51	26.51	157.02
Total	112.13	16.01	128.14	266.26	17.26	283.52	378.39	33.27	411.66

* Upstream from Gravelly Beach to south of Tamar Island.

† Downstream from Gravelly Beach to Ruffins Bay/East Arm.

TABLE 3
Proportion of *Spartina anglica* in sectors of Tamar Estuary
(% of total *Spartina* area)

Survey	Estuary section*	Western shore	Eastern shore	Total
1971/72	Upstream	15.60	46.69	62.29
	Downstream	13.46	24.25	37.71
	Total	29.06	70.94	100.00
1983	Upstream	19.29	50.12	69.41
	Downstream	11.11	19.48	30.59
	Total	30.40	69.60	100.00
1988	Upstream	20.42	44.51	64.93
	Downstream	12.55	22.52	35.07
	Total	32.97	67.03	100.00
1991	Upstream	16.67	45.18	61.85
	Downstream	14.46	23.69	38.15
	Total	31.13	68.87	100.00

* As for table 2.

the total *Spartina* area was sward, with only 14% clumps and shoots, and the proportion of sward subsequently increased to 96% in 1983, and 97% in 1988 and 1991. The variations in total *Spartina* area were reflected in similar trends in sward area, whilst there was a continuous reduction in area of clumps and shoots.

By contrast, in the section downstream of Gravelly Beach in 1971/72 the proportions were almost reversed, with sward covering only 18% of the total *Spartina* area, whereas clumps and shoots covered 82%. However, by 1983 the sward area had increased to 72% of the total, by 1988 to 86%, followed by a small reduction to 83% in 1991. The reduction in total *Spartina* area between 1971/72 and 1983 was mirrored in the reduction in area of clumps and shoots, whilst the sward area increased. Subsequently, changes in the total area were reflected in the increase in sward area to 1988 and its slight reduction in 1991, whilst the area of clumps and shoots decreased slightly to 1988, before increasing slightly to 1991.

When the sections of the Tamar Estuary upstream and downstream of the line through Gravelly Beach are subdivided into eastern and western shores, it can be seen that *Spartina* has colonised very unequally within the four sectors (fig. 5, tables 2 and 3). The upstream eastern shore contained 45–50% of the total area of *Spartina* in the estuary on the different survey dates; the downstream eastern shore contained 19–24%; the upstream western shore contained 16–20%, but the downstream western shore contained only 11–14%. However, the areal distribution of sward and of clumps and shoots during the 20-year period changed in a similar way in the two upstream subdivisions, but in a different but internally similar way in the two downstream subdivisions (as described in more detail above).

CROSS-PROFILE SURVEYS THROUGH SPARTINA MARSH

The replicate cross-profile surveys reveal variations in ground surface height and width of the marsh within the intertidal zone. The site of the Rosevears profile (fig. 1) is an embayment on the upstream western Tamar shore, which contained an extensive *Spartina* sward in 1972, when it was first surveyed in conjunction with boring undertaken to investigate the depth of sediment trapped by the grass (Phillips 1975). A resurvey of this profile in 1977, during the study of the tidal relationships of the marsh (Pringle 1982), revealed that no change had occurred since 1972. However, changes have been apparent since 1977 (fig. 6). The *Spartina* sward extended 4 m landward into the fringe of native saltmarsh plants about HWM between 1977 and 1988. The lower channelward edge of the sward oscillated, showing a retreat of 9 m between 1977 and 1983, followed by an extension of 5 m by 1988, but a small retreat of 1 m by 1991. *Spartina* is an effective trapper of silt brought into the marsh in suspension on the flood tide. The rear and central parts of the marsh have shown slight variations in height, with a net rise of 0.1–0.2 m between 1977 and 1991. The lower part of the marsh, however, has risen steadily to about 0.4 m above its 1977 height. The well-defined continuous lower limit of the *Spartina* sward has been maintained despite the horizontal movements in its position, and it has shown little variation in height, only a slight overall lowering from 1.57 m Low Water Ordinary Spring Tide (LWOST) (Launceston — Batman Bridge) in 1972 to 1.49 m in 1991.

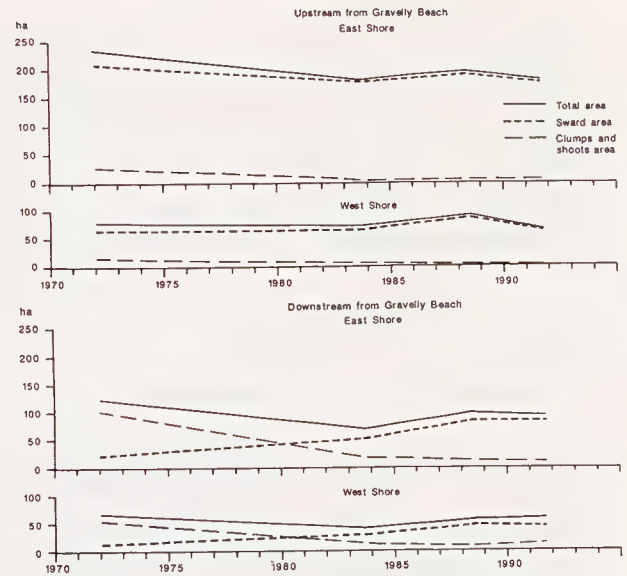


FIG. 5 — Area of *Spartina anglica* in four sectors of Tamar Estuary 1971/72 to 1991.

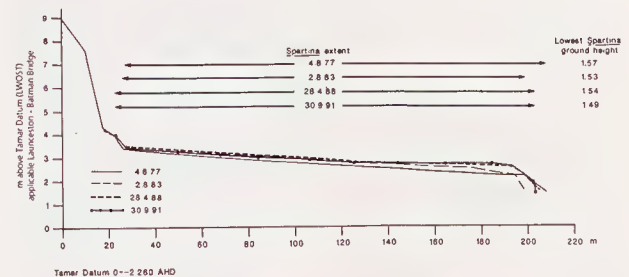


FIG. 6 — Rosevears *Spartina* marsh cross-profiles 1977–91.

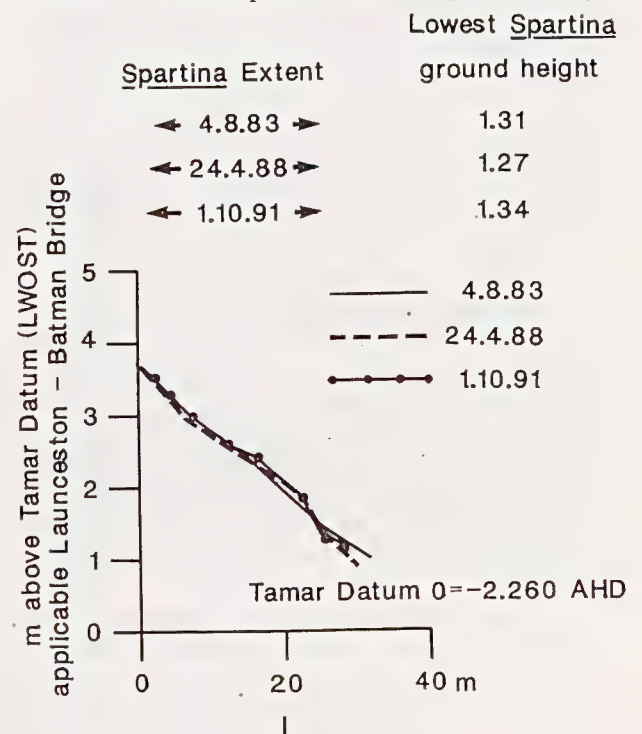


FIG. 7 — Windermere *Spartina* marsh cross-profiles 1983–91.

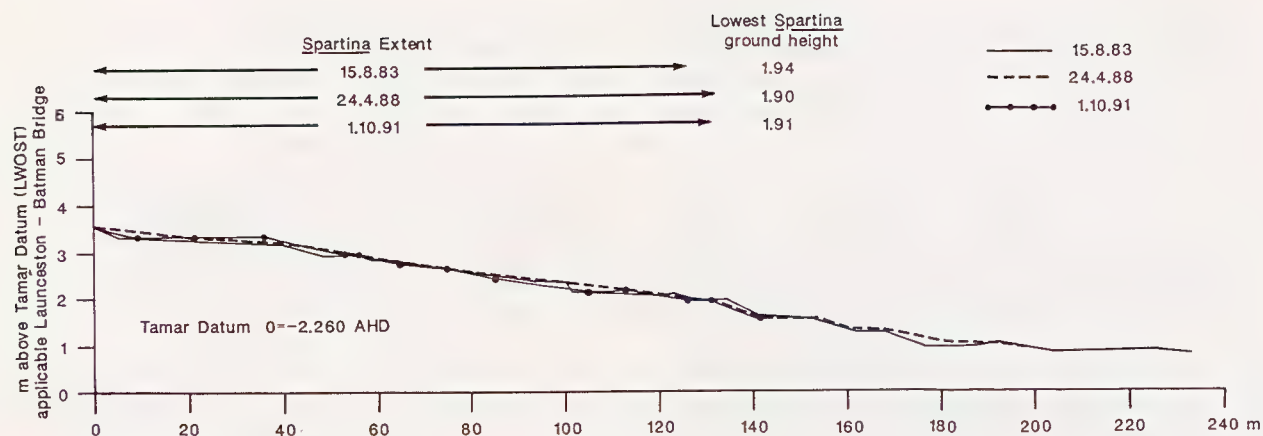


FIG. 8 — *Swan Bay Spartina marsh cross-profiles 1983-91.*

The Windermere profile (fig. 1), established in collaboration with the PLA in 1983, is sited on the same alignment as the Rosevears profile but on the opposite shore of the Tamar. The narrow *Spartina* sward, here growing in mud over basalt, extended 1 m landward between 1983 and 1988 (fig. 7), but otherwise has shown no change in extent up to 1991. Near the rear of the marsh, there have been slight variations in height but no net change between 1983 and 1991, whereas the lower, channelward part rose by 0.1 m. The continuous lower limit showed only a slight variation in height, between 1.31 m LWOST in 1983, 1.27 m in 1988 and 1.34 m in 1991.

Whereas the Rosevears and Windermere profiles are sited in the section of the Tamar upstream from Gravelly Beach, the third profile, established in collaboration with the PLA in 1983, is at Swan Bay, within the downstream section (fig. 1). At the time of the 1971/72 field survey, only clumps and shoots of *Spartina* were colonising this part of the eastern Tamar shore, where ferricrete outcrops extensively. However, by 1983 *Spartina* sward had developed, especially along the upper part of the profile. The upper limit lies at the foot of a concrete revetment, therefore it cannot extend in this direction (fig. 8). The lower edge of the marsh extended 6 m towards the distant channel between 1983 and 1988 but retreated 1 m by 1991. The lower part of the *Spartina* marsh showed slight variations in height between 1983 and 1991 but little net change. The upper part of the marsh, where *Spartina* sward has been longest established, increased in height by 0.1–0.2 m. The discontinuous lower limit of the marsh, where *Spartina* shoots grow amongst ferricrete and oysters, with some mud present, has shown little height variation between 1.94 m LWOST in 1983, 1.90 m in 1988 and 1.91 m in 1991.

The changes described above along the cross-profiles at Rosevears, Windermere and Swan Bay (figs 6, 7 & 8), have been supported also by the results of the annual surveys undertaken by the PLA between 1984 and 1989 (PLA records 1984–89).

INTERRELATIONSHIPS WITHIN THE *SPARTINA* DISTRIBUTION PATTERN

Variations Relating to Geology/Substrate

The overall distribution pattern appears to be strongly influenced by the geology/substrate. The fact that from 45–50% of the total area of *Spartina* in the Tamar Estuary between 1971 and 1991 (table 3) has been in the eastern shore section, upstream from Gravelly Beach, can partly be explained by its long period of colonisation since its introduction at Windermere in 1947. However, it has also been influenced by the extensive intertidal mudflats present at Nelsons Shoal, since, as demonstrated earlier (Phillips 1975), although it is able to colonise any of the rock types and sediments along the shores of the central Tamar Estuary, *Spartina* shows a clear preference for the fine sediment of the intertidal mudflats. Within this upstream eastern section of the estuary, narrow, rocky intertidal zones are found only at Dilston, where dolerite outcrops, and at Windermere, where basalt outcrops downstream of the *Spartina* introduction site. At these points, only a narrow sward fringes the shore, and some of this has been removed by Windermere property owners.

Despite the similar length of time in which *Spartina* has colonised the upstream western shore, only 16–20% of the total area in the estuary is found here. The reasons appear to be that

- the intertidal mudflats form only a narrow strip approximately parallel to the shore;
- there are no extensive shoals or major embayments; also
- outcrops of basalt, between Loch Lea and Rosevears, and of dolerite, between Rosevears and Gravelly Beach, produce narrow, rocky shores, where only a narrow *Spartina* sward has been able to develop.

The rocky basalt shores with little fine sediment, e.g. near Lone Pine Point, continue to provide the least hospitable substrate for the grass (Phillips 1975), as shown by the presence of only coalescing clumps with patches of bare basalt outcrops and pebbles by 1991.

Of the four sections discussed, the downstream eastern shore section contains the second largest area of *Spartina*, covering 19–24% between 1971/72 and 1991. Swan Bay contains extensive intertidal mudflats, but in the smaller bays upstream of Egg Island Point and in Spring Bay and Ruffins Bay, they are less extensive. Ferricrete outcrops on

some of the mudflats. In 1971/72, limited areas of sward had developed near the head of some of these bays, but *Spartina* was present mainly in the earlier colonising form of clumps and shoots. Subsequently, these have coalesced to produce an increasing area of sward. Except for these bays, there are long, rocky shores of dolerite between Swan Bay and Egg Island Point, and of basalt further downstream, colonised only intermittently by *Spartina*, which forms clumps and limited areas of sward, mainly in small bays.

The smallest area of *Spartina*, only 11–14% in the period 1971/72 to 1991, is found in the section which lies downstream of Gravelly Beach on the western shore. It is mainly in the intertidal mudflats in the bay between Little Swan Point and Swan Point, in Supply Bay, Devils Elbow and Ruffins Bay. In 1971/72, there were only small areas of sward, and *Spartina* was mainly in separate clumps and shoots. However, the area of sward has steadily increased up to 1991, as the clumps have coalesced. The rocky dolerite shore, between Supply Bay and the upstream end of Deviot, contains limited areas of clumps and swards, mainly in small bays, but the basalt shore at Deviot was still almost completely clear of the grass in 1991, again indicating the inhospitable nature of this rock for *Spartina* colonisation.

Variations in Area of Sward, Clumps and Shoots, 1971/72 to 1991

The slow initial colonisation of *Spartina* in the Tamar Estuary in the late 1940s and 1950s, followed by its more rapid expansion, especially in the late 1960s to early 1970s, has been considered earlier (Phillips 1975) and reviewed above. The later fluctuations in total *Spartina* area (fig. 2) will now be considered in relation to changes in area of sward and of clumps and shoots in the four sections designated (table 2, figs 3, 4 & 5).

The reduction in total area, from 512 ha in 1971/72 to 367 ha in 1983, resulted from a marked fall in area of clumps and shoots on both eastern and western shores downstream from Gravelly Beach, and a slight fall in their area on both shores upstream. At the same time, the area of sward was clearly increasing on both downstream shores and slightly increasing on the upstream western shore. Only on the upstream eastern shore was there a slight fall in sward area. The overall reduction in area of clumps and shoots suggests that, after the very rapid expansion in area up to about 1971/72, some ecological change or genetic change in the *Spartina* affected mainly the least well-established plants (growing in clumps and as shoots) but had little effect on the swards.

The renewed increase in total area, from 367 ha in 1983 to 447 ha in 1988, resulted from an increase in sward area, although the area of clumps and shoots continued to fall slowly in all the four sections of the Tamar Estuary. The sward area increased partly because clumps and shoots coalesced into this more mature form of marsh, but the sward also spread beyond its earlier limits.

The smaller fall in total area, from 447 ha in 1988 to 412 ha in 1991, occurred mainly on the upstream eastern and western shores and slightly on the downstream eastern shore. However, the total area increased slightly on the downstream western shore. On both upstream shores, the fall was caused mainly by a reduction in sward area, combined with a small decrease in area of clumps and shoots. On the downstream eastern shore, there was a small reduction in

area both of sward and of clumps and shoots. The downstream western shore also showed a slight reduction in sward area, but an increase in area of clumps and shoots, which explains the overall rise in *Spartina* area here.

This second period of overall reduction in *Spartina* area may have had a different cause from the earlier one, between 1971/72 and 1983, because the fall affected mainly *Spartina* sward, especially along both upstream shores. This will be considered further below, in relation to *Spartina* marsh maturity.

Links between Area and Cross-profile Changes 1971/72 to 1991

Although the three cross-profiles have been surveyed regularly only since 1983, it is possible to demonstrate a tentative link between the area changes discussed above and the profile changes. Only the Rosevears profile was surveyed in 1971/72 and 1977 and showed no change in length. However, by 1983, during the period of overall reduction in area, the lower edge of the Rosevears *Spartina* sward had retreated by 9 m (despite a slight increase in total sward area on the upstream western shore including Rosevears).

During the following period of increase in total *Spartina* area, between 1983 and 1988, the lower edge of the Rosevears sward advanced 5 m channelward, whilst the upper edge advanced 3 m landward. Also, the clumps and shoots of the lower part of the Swan Bay profile advanced 6 m channelward. Only the Windermere profile showed no change to its lower edge position, but its upper sward edge advanced 1 m landward. In addition to these profile length changes, the heights of the lower marsh edge lowered from 1.94 m to 1.90 m LWOST at Swan Bay and from 1.31 m to 1.27 m at Windermere.

During the second lesser period of reduction in total area, between 1988 and 1991, the lower edge of the Rosevears and Swan Bay profiles retreated landward by 1 m each, whilst the Windermere profile showed no change. At the same time, the height of the lower marsh edge rose slightly from 1.90 m to 1.91 m LWOST at Swan Bay and from 1.27 m to 1.34 m at Windermere. (Only the Rosevears profile has shown a general trend of lowering of the lower marsh edge between 1977 and 1991, from 1.57 m to 1.49 m.)

MATURING OF THE SPARTINA MARSH

Many of the changes already examined reflect the maturing of the *Spartina* marsh. After its rapid colonisation of the central Tamar mudflats during the 1960s, in the form of shoots which expanded into clumps, some had coalesced into the mature form of sward by the summer of 1971/72. These sward areas were found mainly upstream of Gravelly Beach, including an extensive area on Nelsons Shoal (table 2, figs 4 & 5). The sward developed first near HWM and subsequently extended into the central and lower parts of the intertidal mudflats. In 1971/72, most of these upstream sward areas were fringed with clumps and shoots along their lower edge, but in a few places the sward formed a continuous lower edge near LWM (e.g. near Rostella and around Native Point on the eastern shore; along parts of the Legana shore and at Rosevears downstream of Cimitiere Point on the western shore). Downstream of Gravelly Beach *Spartina*

was mainly growing as shoots and clumps, with only small areas of mature sward mainly in embayments.

By 1983, the *Spartina* marsh had matured considerably, as discussed in detail in a report to the PLA (Pringle 1983). It had extended about 3 km upstream from Dilton and Dog Point, as a sward fringing the lower edge of the native marsh. In the main areas of colonisation in 1971/72, upstream of Gravelly Beach, *Spartina* formed a sward with a continuous lower limit at about high low water mark (HLWM) by 1983. This appeared to represent the maximum possible extent of the marsh towards the channel, under ecological conditions prevailing at that time. In places (e.g. near the Rosevears cross-profile line, fig. 6), a small erosional cliff had formed since 1971/72 along the lower marsh edge, and this had reduced the total area of sward. In a few areas (e.g. around Nelsons Shoal, in Muddy Creek and along the basalt shores at Windermere and near Lone Pine Point), the *Spartina* sward was still fringed with clumps and shoots, indicating that it had not yet reached its fully mature extent.

Dowstream of Gravelly Beach, by 1983, the maturing of the marsh was indicated by the increase in sward area (figs 4 & 5), as clumps and shoots coalesced. Occurring mainly in the bays, this produced larger areas of sward than in 1971/72, although these continued to have a fringe of clumps and shoots along their lower edge, indicating that full maturity had not yet been reached. However, some of the earlier areas of clumps and shoots had been lost, giving the overall reduction in *Spartina* area between 1971/72 and 1983.

Since 1983, the trend towards a mature *Spartina* sward has continued steadily throughout most of the central Tamar estuary. Upstream of Gravelly Beach, the area of sward expanded channelward in many places up to 1988 but continued to show a well-defined continuous lower limit. Since 1988, it has suffered a little erosion and retreat. A fringe of clumps and shoots is still present along the same sections of marsh as in 1983, most notably on the downstream side of Nelsons Shoal. The younger marsh, downstream of Gravelly Beach, showed mainly an expansion of sward, as clumps and shoots coalesced, but on the western shore, since 1988, the sward area has been reduced slightly, whilst the area of clumps and shoots has expanded. Even the most extensive areas of sward still had a fringe of clumps and shoots in 1991, indicating that they were not fully mature.

Periods of overall expansion of *Spartina* marsh have been achieved primarily by the extension of sward channelward; and also laterally where space permitted. Reductions in overall area have been achieved in different ways, depending on the state of maturity of the marsh. At the earlier stage, between 1971/72 and 1983, the reduction resulted from the loss of clumps and shoots primarily, whilst during the later stage, between 1988 and 1991, it resulted mainly from erosion along the lower edge of the sward. In both cases, the lower edge of the *Spartina* marsh retreated shorewards. There may be a number of reasons for the varying position of the lower edge through time.

Tidal Influences on the Lower Marsh Edge

The tidal regime of the Tamar Estuary is transitional between semi-diurnal and diurnal (Pringle 1982), with a characteristic tidal sequence of low low, low high, high low, high high. Successive high tides have only about half the height difference experienced by successive low tides.

The tidal immersion of the marsh was examined for 1977, with particular reference to the mature Rosevears marsh, where the maximum spring tide range was 3.9 m and the minimum neap range was 2.1 m. The marsh cross-profile was related to recorded and predicted tidal curves, in order to investigate variations in depth and period of immersion in different parts of the marsh. This revealed that, whilst the whole marsh was immersed on all high tides to a depth of between 0.2 m and 1.0 m above ground level near its upper limit, the lower limit lay at the height of the highest high low tides but fully emerged on all low low tides.

As Hubbard (1969) indicated, the tidal immersion of a marsh may alter many environmental conditions within the habitat, including moisture content, salinity, aeration, light intensity and duration, and temperature, in addition to physical changes produced by intermittently present wave and current action. Ranwell *et al.* (1964) indicated that the tidal immersion limit for *Spartina* in Poole Harbour, Dorset, UK was 5800 hr^{-1} , whereas the tidal immersion time for the Rosevears *Spartina* marsh was 6650 h for 1977 (Pringle 1982). Hubbard (1969) observed that the maximum continuous immersion of the lowest level of the Poole Harbour marsh was 23.5 h per day during a neap winter tide; this was similar to conditions on the Rosevears marsh on the highest HLWs between May and July in 1977.

As the cross-profiles have shown, the height of the lowest *Spartina* growth has varied only slightly at each locality: at Rosevears 1.49–1.57 m LWOST (Launceston — Batman Bridge), at Windermere 1.27–1.34 m, and at Swan Bay 1.90–1.94 m. This does suggest there is a limiting control operating. It was demonstrated earlier (Pringle 1982) that the lowest *Spartina* level at Rosevears in 1977 (1.57 m) was at the height of the highest HLW level for that year, and small variations may result from changing tidal conditions from year to year. The reason for the difference between Rosevears and Windermere heights of about 0.2 m is more difficult to explain, as the two sites are opposite each other on western and eastern Tamar shores respectively. Strong tidal currents occur in this relatively narrow constricted section of the estuary, and general observations indicate that, on the flood tide, higher velocities occur near the Rosevears shore than along the Windermere shore; this pattern may be reversed on the ebb tide. This could produce a lateral surface water gradient downwards towards the area of fastest ebb flow and, if so, might depress the LW level at Windermere slightly. In addition, the rocky basalt substrate at Windermere provides a firmer anchor for the plants than the finer sediment substrate at Rosevears; this may enable them to grow to a slightly lower level.

An increase in tidal range occurs from the mouth of the Tamar Estuary towards its head at Launceston. Foster *et al.* (1986), in a series of tidal measurements in March–April 1985, demonstrated a variation between MHW and MLW of 2.34 m at Georgetown and 3.25 m at Launceston. The variation between 2.54 m at Deviot and 2.81 m at Rosevears helps to explain the difference in the height of the lower edge of the *Spartina* marsh at Swan Bay as compared with that at Rosevears. In addition, the Swan Bay site lies in a broader section of the estuary, well away from the strong tidal currents of the channel.

Meteorologically Controlled Influences on the Lower Marsh Edge

As well as the tidal control on the position and height of the lower limit of the *Spartina* marsh, this edge will also be influenced by variations in river discharge into the estuary. The main catchments are those of the North Esk River (1067 km²) and South Esk River (8609 km²) (fig. 1). Foster *et al.* (1986) demonstrated seasonal variations in flow, with highest flows in winter and spring and lowest flows in summer and autumn reflecting the rainfall pattern. The Trevallyn/Poatina Hydro-Electric Power Scheme, which came into operation in two stages, in 1955 and 1965, with a subsequent addition in 1977, has involved the diversion of water into the South Esk from the Great Lake under low flow conditions. This has reduced the incidence of low river flow into the Tamar. However, because the Trevallyn reservoir is small, it has little effect on flood flows into the estuary, and it is the frequency and height of flood events which may influence the lower limit of the *Spartina* marsh.

In addition to influencing river discharge, meteorological conditions may affect tide height and tidal current velocities, through strong winds and atmospheric pressure variations. Foster *et al.* (1986) suggested that resulting storm surges develop in Bass Strait and may result in variations in tide levels in the Tamar Estuary of 0.5–1 m. Strong winds, which they found were mainly from between WNW and NNW and were associated with high pressure, distort the shape of the tidal curve in the estuary, and this effect becomes more marked with distance up the estuary. The duration of the flood tide is increased, whilst the ebb is decreased. Therefore, flood tide velocities are decreased whilst ebb velocities are increased.

Human Influences on the Lower Marsh Edge

As well as being influenced by normal astronomical tide conditions, the lower edge of the *Spartina* marsh may also be affected, therefore, by such meteorologically controlled events as river floods and abnormal tidal variations. There may be a human influence as well. Launceston was the main port on the Tamar Estuary between about 1800 and the mid-1960s; after 1890, dredging was needed to enable increasingly large ships to pass along the estuary. After the mid-1960s, port facilities were moved downriver to Bell Bay to cater for larger container ships and, therefore, dredging was reduced. This has affected not only the main channel, and tidal velocities within it, but also sedimentary conditions on the adjacent mudflats. Although commercial shipping has been reduced in the Tamar in recent decades, recreational pleasure boat activities have increased and, as Foster *et al.* (1986) noted, this may lead to a pronounced increase in mudbank erosion and release of suspended sediment.

Influences on the Upper Marsh Edge

In describing the maturing of the *Spartina* marsh, it was noted that the upper edge had extended slightly shoreward in some places into the narrow zone of native Tasmanian saltmarsh vegetation about HWM. The marsh first reaches the mature sward stage near its upper limit and further changes have been observed here in certain localities since 1983. During the winter, when most of the plant above the

ground surface dies back, some is broken off by wave and tidal action. It floats in the tidal currents before being deposited in some relatively sheltered bays, or near HWM along shores with a particularly long fetch. This can form such a thick thatch that the plants buried beneath it are unable to sprout and grow through it during the following spring and summer. As a result, by 1991 a strip of earlier sward up to about 25 m wide near HWM had been destroyed, especially in embayments in the more mature marsh upstream of Gravelly Beach, and also in Swan Bay and near Swan Point downstream.

This trend may be expected to continue and even escalate because, as the sward area increases with the whole Tamar *Spartina* marsh maturing further, the quantity of dead plant remains will increase each winter. Slightly offsetting this is the human effect produced by removal of dead thatch from more accessible shores for use as a garden mulch.

CONCLUSIONS

Physical Effects of *Spartina* Colonisation on the Tamar Estuary

The colonisation of large areas of the Tamar Estuary intertidal mudflats by *Spartina*, since its introduction from England via South Australia in 1947, has had considerable physical effects (in addition to the biological changes which are outside the scope of this paper). After rapid expansion to cover over 500 ha in the 1971/72 summer, it was reduced but has shown fluctuations in total area up to 1991, when it covered 412 ha. It has at least partially fulfilled the aims of the introduction, to stabilise and raise the mudflats and to constrain channel movements.

Borings through the mature Rosevears and Windermere marshes in 1972 revealed *Spartina* root remains in fine sediment to maximum depths of 2.29 m and 2.35 m respectively (Phillips 1975). Foster *et al.* (1986) compared three cross-sections of Nelsons Shoal surveyed in 1986 with a survey of the whole shoal by Clerke in 1889, and deduced that it has acted as a substantial sediment sink, especially in the now *Spartina*-covered areas where about 1 m of siltation has occurred. They estimated that *Spartina* was colonising about 5.3 km² of Nelsons Shoal in 1986 and that the total quantity of sediment trapped in this area during the 97 years was between 5 and 10 million m³ or 50 000 to 100 000 m³y⁻¹. The replicate cross-profile surveys discussed in this paper have revealed maximum rises of 0.4 m along the lower part of the Rosevears profile 1977–91; 0.1 m along the lower part of the Windermere profile 1983–91; and 0.1–0.2 m along the upper part of the Swan Bay profile 1983–91.

As the mature *Spartina* sward, which was well-developed above Gravelly Beach by 1983, extends down to about HLWM, the main channel is constrained within narrower limits than before the grass was introduced. However, in the narrow sections of the estuary especially, waves and tidal currents are able to erode the lower marsh edge at times.

Whilst these effects of stabilising the mudflats by trapping silt and constraining the main channel may be regarded as beneficial, *Spartina* colonisation is seen as detrimental in some other ways. Through its vigorous growth, it has engulfed many small jetties and invaded sand beaches from the mudflats to reduce the recreational facilities and attractions of the Tamar shores.

Spartina Control

After the explosive spread of *Spartina* in the late 1960s to early 1970s, its colonisation of the mudflats has been largely uncontrollable. Herbicides proved to be ineffective, mainly because of the tidal regime in which every HW immerses the whole marsh at least near ground level. In addition, there have been concerns about unwanted side effects, which were felt especially during a period of commercial oyster cultivation in the estuary.

Regular physical removal by digging out was practised by the PLA, during the 1980s, at a number of recreationally important sites, and by other bodies. This proved successful but was labour intensive. Individual property owners have employed similar methods, together with burning the grass along their shore; others mow it to reduce it to a short turf, which allows easy access to small jetties. On a larger scale, cattle and sheep are grazed on the *Spartina* marsh where the substrate is relatively firm, e.g. in Spring Bay and Redwood Bay. It provides valuable fodder, especially towards the end of summer when the pastures are drying; the cattle reduce the *Spartina* height to about 80 mm, while the sheep reduce it to about 20 mm. Whilst all these methods have been reasonably successful, they are controlling only a very small proportion of the total *Spartina* area in the Tamar Estuary.

The Future for *Spartina* in the Tamar Estuary

The colonisation and effects of *Spartina* have been examined mainly for the period 1971–91. Whilst most of the *Spartina* marshes reached the mature sward stage in the estuary upstream of Gravelly Beach, there were still, in 1991, some areas of bare mudflats above the general lower limit of HLWM, the most extensive of which lies along the downstream side of Nelsons Shoal. The sward can be expected to extend into these. The fluctuations observed along the mature lower marsh edge are likely to continue, primarily as a result of variations in tidal conditions and river discharge. The death of a belt of sward near HWM, as dead winter thatch stifles subsequent growth, is likely to become more extensive along the shore, as long as summer growth rates in the marsh generally are maintained. Mature marsh levels are expected to rise as the grass continues to trap sediment brought onto the marsh in suspension on the flood tide.

Downstream of Gravelly Beach, the less mature *Spartina* marsh is expected to continue its development towards maturity, firstly in the embayments with mudflats. Some extension of the marsh along the rocky shores may occur slowly to produce a narrow fringe of sward. The death of a belt of sward near HWM, already occurring especially in Swan Bay and near Swan Point, is likely to extend further at the rear of expanding areas of mature sward. When sward has extended to HLWM it may be expected to show similar fluctuations in position to those already seen upstream of Gravelly Beach, and the mature marshes will rise as they trap sediment.

All these projected changes are likely to take place in the estuary between about Tamar Island upstream and East Arm downstream. As there has been no significant extension upstream since 1983, nor downstream since 1972, it seems unlikely that this will occur naturally in the near future.

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ECOLOGICAL STUDIES OF VEGETATION IN SHORT-TAILED SHEARWATER COLONIES IN TASMANIA

by M.J. Brown, N. Maruyama and K.J. Williams

(with two text-figures and three tables)

BROWN, M.J., MARUYAMA, N. & WILLIAMS, K.J., 1993 (31:viii): Ecological studies of vegetation in short-tailed shearwater colonies in Tasmania. *Pap. Proc. R. Soc. Tasm.* 127: 11–16. Forestry Commission, 199 Macquarie Street, Hobart, Tasmania, Australia 7000 (MJB and KJW); University Tokyo Noko, Tokyo, Japan (NM).

Extensive modification of coastal vegetation at the Pineapples and Cape Deslacs rookeries is related to the burrowing, trampling and guano deposition of short-tailed shearwaters (*Puffinus tenuirostris*). Ordination and classification of the associated vegetation and measurement of soil nutrient levels demonstrate two distinct but interacting phases of vegetation succession. These are affected by coastal influence, edaphic factors and the presence or absence of nesting areas.

Key Words: vegetation, soil nutrients, shearwater, ecological studies, Tasmania.

INTRODUCTION

The short-tailed shearwater (*Puffinus tenuirostris*) is a major ecological, cultural and sometimes economic feature of the Tasmanian coastal landscape.

In a classic series of papers, Gillham (1958, 1960, 1961, 1965) elucidated the characteristics of the vegetation of Tasmanian short-tailed shearwater colonies in the Furneaux Group of islands in Bass Strait. Her papers also provide some indications of the soil conditions which prevail at rookery sites.

During the 1970s and 1980s staff from the State Wildlife agency (currently the Parks and Wildlife Service, Department of Environment and Land Management) have continued the long-term studies, begun in the late 1950s by D. Serventy and then carried on by V. Serventy, into the life cycle and dynamics of the short-tailed shearwater (e.g. Serventy 1958, 1967, 1968, Skira *et al.* 1986). These studies have been broadened to encompass statewide inventory and monitoring of the effects of commercial and non-commercial exploitation of the birds for human consumption (e.g. Naarding 1981, Skira 1990).

The succession of vegetation in coastal areas of Tasmania has been examined in detail at several sites around the state. Thus Bowden & Kirkpatrick (1974) have outlined the progression of vegetation from the shore to the saltmarsh hinterland at Rheban Spit in the southeast and Brown (1980) outlined a putative successional scheme for the western coastal vegetation at Mt Cameron West. More recently Chladil & Kirkpatrick (1989) undertook a quantitative study of the dune vegetation at Asbestos Range National Park in the north.

Whilst there has been considerable study of the birds and of their habitats, there has been little attempt to relate the dynamics of the birds *in situ* and the ecological succession of vegetation at the rookeries. The present paper attempts to provide a first examination of these interrelationships at two rookeries, Pineapples and Cape Deslacs, and includes relevant comment from elsewhere.

METHODS

Studies of Site Vegetation and Soil

The vegetation at Pineapples and Cape Deslacs (fig. 1) was sampled on several occasions during Dec/Jan 1987/88 and in 1989/90 using 2×2 m quadrats. Each species was scored for its abundance using a modified Braun-Blanquet score. Vascular plants only were scored. The species nomenclature used in this paper follows Buchanan *et al.* (1989). The species presence data from Pineapples were subjected to ordination and classification using detrended correspondence analysis (DCA) and TWINSpan respectively (Hill 1979a, b). Only two axes were selected from the ordination, as the later axes are known to be non-linear combinations of axes one and two (P. Minchin, pers. comm.).



FIG. 1 — Locations of study sites: (1) Pineapples; (2) Cape Deslacs.

Total vegetation cover, rock cover and sand cover was classified, and an assessment was made of the number of burrows, the recency of occupancy and the amount of disturbance at each site.

Soils were collected at Pineapples (14 samples) and at Cape Deslacs (17 samples) to encompass the range of vegetated environments encountered at each site. Soil analyses were conducted for us by the Tasmanian Department of Primary Industry's analytical laboratories. Soil characteristics measured were pH (aqueous extract), conductivity (aqueous extract), P, K, N, Ca, Mg and Na (bicarbonate extract). Organic carbon content was requested but measurement facilities were not available.

In order to analyse numerically the relationships between soils and the vegetation, the data from Pineapples were subjected to factor analysis and subsequent varimax rotation. The DCA scores were incorporated into these analyses together with pH, conductivity and the logarithms of the concentrations of P, K, N, Ca, Mg, and Na in ppm.

Site Descriptions

The rookeries at Pineapples are underlain by aeolian sands which, in turn, overlie Jurassic dolerite. The rookeries are on an exposed westerly aspect and extend from a few metres inland of the unvegetated coastal rocks to about 300 m inland. The area was burnt in the bushfires of 1966/67, and parts of the area were burnt again in 1982.

The cliffs at Cape Deslacs are formed of Permian sediments (Parmeener supergroup) and rise to 54 m. These cliffs are also overlain by aeolian sands, which are of sufficient depth to support short-tailed shearwater colonies. The colonies here are found on all aspects, the bluff forming an indented headland which projects into the sea to the southeast and which also falls away from a high point towards the north. The rookeries occupy the cliff tops and extend about 150–200 m inland. This area was probably also burnt in 1967, but no clear evidence of the age of the vegetation was obtained.

RESULTS

The results of the analysis by Twinspan are shown in table 1. The descriptions of the communities at Cape Deslacs and at Pineapples which follow are based on this classification but have been modified to accord with field observations.

The Vegetation

The plant communities at both sites are of similar composition. Near the coast there is a halophytic community dominated by various combinations of *Disphyma australe*, *Tetragonia implexicoma*, *Carpobrotus rossii*, *Stipa stipoides*, *Leucopogon parviflorus*, *Poa poiformis*, *Poa labillardieri*, *Scirpus nodosus* and *Rhagodia baccata*. These communities have a range of structures depending on their physiographic situation. On deep soils on cliff ledges and declivities, the shrubs predominate and form open shrublands, whilst open grasslands of *Stipa stipoides*/*Poa poiformis* or succulent herbfields occur on the shallow soils of the exposed cliff tops

and rock faces. Other cliff top shrub elements include *Helichrysum reticulatum* and *Olearia phlogopappa*.

Small saline soaks and wet patches are found on drainage lines in shallow soils of the cliffs and support non-succulent salt-tolerant species such as *Juncus kraussii*, *Lobelia alata*, *Gahnia filum* and *Schoenus nitens*. Where there are no burrows, the vegetation consists of dry or wet heaths dominated by *Banksia marginata* together with Epacridaceae such as *Epacris impressa*, *E. lanuginosa* and *Sprengelia incarnata*, Fabaceae (*Aotus ericoides*, *Pultenaea* spp.), *Acacia* spp.) and Myrtaceae (*Leptospermum scoparium*, *L. glaucescens*, *L. lanigerum*, *Melaleuca squarrosa*, *M. gibbosa* and *M. squamea*). The heaths are the most species-rich communities at both locations. The vegetation grades through scrubs of *Leptospermum* spp. and *Melaleuca* spp. of low diversity to heathy woodlands dominated by *Eucalyptus viminalis* or *E. obliqua*. The structural and floristic variation in the vegetation is strongly conditioned by exposure, soil depth, fire and drainage.

Thus the halophytic communities develop on the most exposed coastal onshore areas, with the heaths occupying the deeper aeolian sands. *Melaleuca* and/or *Leptospermum* scrubs develop along drainage lines or small creeks, and the *Eucalyptus* woodlands are found on more sheltered sites on deeper soils. Frequent fires promote the heath vegetation at the expense of the scrubs. In the prolonged absence of fire, much of the heath containing the dominant *Leptospermum* or *Melaleuca* species would succeed to scrub, with a corresponding loss of species richness. On the other hand, too frequent fire promotes bracken. In the woodlands, infrequent fires result in a heathy or shrubby understorey. Very frequent, low-intensity fires result in bracken understoreys where the soils are sandy but tend to grassy understoreys where the overlying aeolian sands are shallow or where there has been admixing of the nutrient rich dolerite sub-soils and the sands.

The shearwater colonies are found on the deeper sands of the hinterland. Three main communities can be recognised: (1) an open community of *Poa labillardieri*/*P. poiformis* and *Lomandra longifolia*, with considerable bare areas and a variable cover of introduced annual species such as *Bromus diandrus*, *Agropyron repens*, *Cirsium vulgare*, *Hordeum leporinum* and *Holcus lanatus*; (2) a dense community dominated by *Pteridium esculentum*, with few other species present; (3) a succulent halophytic herbfield community of variable cover but containing *Carpobrotus rossii*, *Tetragonia implexicoma*, and *Rhagodia baccata*, either in pure stands or in any combination.

These three communities represent different successional stages in the life of the rookery. The main determinants of the community present at any one site are degree of trampling and guano deposition, degree of incorporation of dead grass and other organic matter into the soil by the birds, and the effects of fire. The birds thus provide a strong biogenic control over the traditional successional pathways which are found in coastal areas where the birds are absent (e.g. Jackson 1968, Kirkpatrick 1977, Brown 1980, Brown & Podger 1982). The ordination by detrended correspondence analysis (DCA) of the Pineapples rookery is shown in figure 2. The encircled quadrats are the four major groups recognised in the Twinspan classification (see table 1). It can be seen from the ordination that the first axis aligns the sites from those with high DCA scores for the heath plots and no burrows, through intermediate values representing

TABLE 1
TWINSPAN analysis of Pineapples Rookery vegetation data

Vascular plant species	Burrow-rich sites, deep sandy soils	Coastal sites, shallow soils	Bracken- rich sites	Heath/scrub sites, no burrows	Twinspan divisions (3)
<i>Acaena novae-zelandiae</i>	-----1-----	1-11---1	1-----	-----	000
<i>Juncus pallidus</i>	---1-----	1---11-	--1----	-----	000
<i>Leucopogon australis</i>	-----	-----1-	-----	-----	000
<i>Lobelia alata</i>	-----	11111111	1-----	-----	000
<i>Agrostis avenacea</i>	-----	1-----	-----	-----	000
<i>Apium prostratum</i>	-----	1---1---	-----	-----	000
<i>Baumea juncea</i>	-----	11111---	-----	-----	000
<i>Epilobium billardierianum</i>	-----	1-----	-----	-----	000
<i>Gahnia filum</i>	-----	11-11---	-----	-----	000
<i>Helichrysum reticulatum</i>	-----	-----1---	-----	-----	000
<i>Juncus kraussii</i>	-----	1-----	-----	-----	000
<i>Oxalis corniculata</i>	-----	1-1-----	-----	-----	000
<i>Rumex crispus</i>	-----	1--1--1-	-----	-----	000
<i>Stipa stipoides</i>	-----	---1---	-----	-----	000
<i>Veronica gracilis</i>	-----	1-----	-----	-----	000
<i>Sonchus megalocarpus</i>	-----1-----	--111---	-----	-----	000
<i>Cirsium vulgare</i>	-----11-----	1-----1-	-----	-----	001
<i>Scirpus nodosus</i>	---1---11111111-11	111---1-	-----	---1-----	001
<i>Bromus diandrus</i>	---111111-1-1-11-	-----1	-----	-----	001
<i>Carpobrotus rossii</i>	1-1-11111111111-1--	11--1---	-----	-----	001
<i>Holcus lanatus</i>	---11-----	-----	-----	-----	001
<i>Hordeum murinum</i> ssp. <i>leporinum</i>	---11-1--	-----	-----	-----	001
<i>Solanum laciniatum</i>	-----111---	-----	-----	-----	001
<i>Rhagodia baccata</i>	11-1-----	-----	-----	-----	001
<i>Tetragonia implexicoma</i>	11-1---1--11111---	1-----	-----	--1-----	001
<i>Poa labillardieri</i>	-1---1--111-11-111111	11111111	1-1----	-----11--	001
<i>Lomandra longifolia</i>	111-1-1-----1111--1	1111--11	1---1-1	11-11111-1	010
<i>Pteridium esculentum</i>	1-11--1---1-111--111-	---1-111	1111111	11111111-1	010
<i>Senecio vulgaris</i>	1-----	-----	1-----	-----	010
<i>Dianella tasmanica</i>	--11-----	---1-111	1--1--	-----1--	011
<i>Leucopogon parviflorus</i>	-----	-----1	1-----	-----	011
<i>Goodenia ovata</i>	-----	----11-	111----	----111--	10
<i>Melaleuca gibbosa</i>	-----	---1--1	1-----	----1111-	10
<i>Melaleuca squarrosa</i>	-----	----1--	111----	----1111--	10
<i>Eucalyptus obliqua</i>	-----	-----	-----1	---1-----	110
<i>Hydrocotyle hirta</i>	-----	-----	1-----	-----	110
<i>Leptospermum scoparium</i>	-----	-----1	1-1----	--11111111	110
<i>Olearia floribunda</i>	-----	-----	-----1	-----11-1	110
<i>Gahnia grandis</i>	-----	-----	1-----	----1111-	111
<i>Acacia myrtifolia</i>	-----	-----	-----	---1111111	111
<i>Acacia verticillata</i>	-----	-----	-----	---1-----	111
<i>Amperea xiphoclada</i>	-----	-----	-----	1---1111-1	111
<i>Baumea acuta</i>	-----	-----	-----	-----1---	111
<i>Allocasuarina monilifera</i>	-----	-----	-----	-11-1111-1	111
<i>Cassytha glabella</i>	-----	-----	-----	---1-----	111
<i>Epacris impressa</i>	-----	-----	-----	---1111-1	111
<i>Gonocarpus tetragynus</i>	-----	-----	-----	---11--1	111
<i>Lepidosperma laterale</i>	-----	-----1-	-----	1--111111-	111
<i>Leptocarpus tenax</i>	-----	-----	-----	---111---	111
<i>Olearia phlogopappa</i>	-----	-----	-----	1-----	111
<i>Pultenaea juniperina</i>	-----	-----	-----	-----1--	111
<i>Tetrarrhena distichophylla</i>	-----	-----	-----	-----1-1-1	111
<i>Banksia marginata</i>	-1-----	-----	-----	1--11--11	111
<i>Leptospermum glaucescens</i>	---1-----	-----	-----	111-----1	111
<i>Helichrysum scorpioides</i>	-----	-----	-----	-----1-11	111
<i>Lindsaea linearis</i>	-----	-----	-----	---1--1-	111
<i>Selaginella uliginosa</i>	-----	-----	-----	-----1--11	111
<i>Aira caryophyllea</i>	-----	-----	-----	-----1-	111
<i>Aotus ericoides</i>	-----	-----	-----	-----1	111
<i>Epacris lanuginosa</i>	-----	-----	-----	-----1-	111
<i>Gompholobium huegelii</i>	-----	-----	-----	-----1	111
<i>Gonocarpus teucroides</i>	-----	-----	-----	-----1-	111
<i>Lagenifera stipitata</i>	-----	-----	-----	-----1	111
<i>Leucopogon collinus</i>	-----	-----	-----	-----1	111
<i>Opercularia varia</i>	-----	-----	-----	-----1	111
<i>Patersonia fragilis</i>	-----	-----	-----	-----1	111
<i>Pultenaea stricta</i>	-----	-----	-----	-----11	111
<i>Deyeuxia quadriseta</i>	-----	-----	-----	-----1	111
<i>Sprengelia incarnata</i>	-----	-----	-----	-----11	111
<i>Stylidium graminifolium</i>	-----	-----	-----	-----1	111
<i>Xanthosia pilosa</i>	-----	-----	-----	-----11	111
<i>Lepidosperma concavum</i>	-----	-----	-----	-----1	111
<i>Schoenus tenuissimus</i>	-----	---1---	-----	----1-111	111
Twinspan divisions, two levels	00000000000000000000	00000000	1111111	1111111111	
	00000000000000000000	11111111	0000000	1111111111	

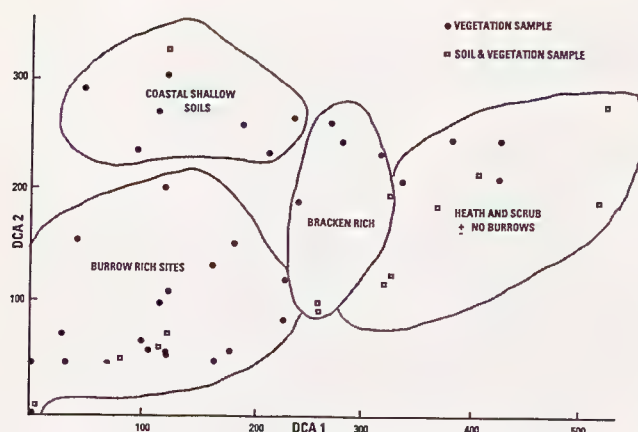


FIG. 2 — Ordination of sites at Pineapples rookery by Detrended Correspondence Analysis of their floristics. Sites where soils samples were taken are indicated.

scrub and woodland plots, again with few or no burrows, to sites with old burrows and thence to the lowest DCA score sites with high densities of currently active burrows. Some of the sites having low scores are very rocky, with only very shallow sandy soils. The second axis contrasts these shallow soil sites with the deep sandy sites of high burrow density.

Soil Nutrients

The complete soils data are given in table 2. The results of the factor analysis and varimax rotation are given in table 3. There are highly significant differences for nutrient status between the rookery and non-rookery sites at both locations, with elevated P and N concentrations to be found, as expected, on the sites of highest burrow density and/or bird activity ($F = 6.06$, $P < 0.05$ for phosphorus and $F = 7.07$, $P < 0.05$ for nitrogen). There were no significant interaction effects found in the ANOVA for P, but there was a highly significant site/burrow occurrence interaction

TABLE 2
Soil chemical analyses from Pineapples and Cape Deslacs rookeries

Site*	Burrows	pH	Conductivity TDS (mS)	Elements (ppm)					
				P	K	N	Ca	Mg	Na
1	+	4.6	0.40	014	120	3700	359	271	352
1	+	4.4	0.33	19	100	3000	381	171	180
1	—	4.2	0.24	14	60	400	454	223	168
1	+	4.6	0.18	45	80	1400	117	32	45
1	+	5.1	0.14	12	50	3000	201	101	130
1	+	4.5	0.23	140	80	3000	186	121	152
1	+	6.1	0.43	14	320	3400	311	394	518
1	+	5.0	0.94	53	310	4000	685	311	713
1	+	4.6	0.37	130	90	4500	274	91	112
1	+	4.7	0.38	28	90	1600	195	216	353
1	—	4.9	0.22	9	120	700	107	128	210
1	—	5.2	0.24	9	90	1100	242	465	287
1	—	4.9	0.16	5	80	800	81	210	170
1	—	4.9	0.09	6	50	1600	337	387	139
2	+	5.3	0.15	17	80	800	216	120	198
2	+	5.3	0.10	24	50	200	41	28	82
2	+	5.3	0.12	16	60	400	95	68	111
2	+	5.7	0.08	29	60	300	109	89	81
2	—	6.1	0.16	5	350	800	230	503	388
2	—	5.6	0.37	12	310	1100	628	223	352
2	+	5.3	0.16	9	30	200	56	58	87
2	+	5.5	0.25	6	140	700	158	159	314
2	+	5.4	0.15	13	50	400	150	125	106
2	+	6.1	0.04	1	40	200	65	64	46
2	+	5.7	0.10	56	60	600	201	64	96
2	+	5.7	0.22	48	70	900	333	165	184
2	—	6.0	0.26	5	220	700	471	310	527
2	—	6.1	0.22	6	300	900	438	384	410
2	—	6.2	0.28	8	380	1800	211	495	749
2	—	6.7	0.55	9	380	1400	681	365	710
2	—	6.1	0.23	7	130	500	196	121	247

* 1 — Pineapple; 2 — Cape Deslacs.

TABLE 3
Varimax rotated factor matrix of soil
variables and ordination scores*

Variable	R.F.1	R.F.2
pH	0.523†	-0.058
TDS	0.790	0.435
log P	-0.102	0.905
log K	0.789	0.356
log N	0.316	0.738
log Ca	0.644	0.226
log Mg	0.770	-0.459
log Na	0.940	-0.064
DCA1	-0.260	-0.920
DCA2	0.457	-0.583

* Data from the Pineapples rookery

† Bold type indicates values greater than 0.5
irrespective of sign.

for N ($F = 32.36$, $P < 0.001$), reflecting the high variability of the soils at the Pineapples, where the differences between the high N concentrations in the bare areas and those of the heaths are very much more pronounced than in equivalent areas at Cape Deslacs, where no clear differences between burrow and non-burrow vegetation were apparent. That this trend is reflected in the vegetation composition is borne out clearly in the varimax rotation scores (table 3). Interestingly, the first factor reflects a saline influence, with Na, TDS, K, Mg and Ca being most highly weighted. Neither DCA axis is aligned strongly with this factor, suggesting that the major compositional trends in the vegetation are related to factors other than direct salinity effects, at least at this site, over the range of concentrations recorded. The direction of floristic variation may also be oblique to the direction of the salinity gradient. However, the second factor axis shows a very strong relationship between DCA 1, the major vegetation gradient, and a combination of N and P concentration, i.e. soil variables which relate directly to nutrient status. In fact, the second DCA axis grades the sites in order of soil depth, amount of organic matter incorporated in the soil (chiefly grass) and the density of burrows in combination. Thus it appears that, given the halophytic natures of the species involved, the succession of vegetation in the area is biogenically determined and does not reflect directly the usual underlying physical parameters, such as rock type, drainage or onshore effects of salinity. There is some evidence in the field of the residual vegetation which is so determined; e.g. the TWINSpan analysis separates the group of *Melaleuca* spp. characteristic of poorly drained sites.

DISCUSSION

The vegetation of shearwater rookery sites is subject to stresses additional to those offered elsewhere in coastal environments. Surface-nesting birds, such as albatross and cormorants, give rise to considerable trampling and, of course, high levels of guano deposition. Guano is rich in phosphorus and nitrogen to the extent that it can be phytotoxic, especially in regions subject to drought (Gillham 1960). The vegetation in nesting areas of burrowing birds

is prone to disturbances similar to those caused by surface-nesting birds but the burrows are usually (and necessarily!) located in areas of deeper soil development. Here, the use of sites is dependent on depth and friability of soils and on the likelihood of the burrow sites remaining free from inundation by water or from structural collapse, for the duration of use.

The shearwaters alter the habitat in the same way as surface-nesting birds by guano deposition and by trampling (especially in marshalling areas), but they also redistribute and incorporate surface organic matter into the soil, and they increase the degree of aeration of the soil volume.

The mechanical damage caused by the birds can lead to soil compaction ("hard ground") and also to pedestalisation of *Poa* tussocks. The bare areas are eventually colonised by *Tetragonia* and *Carpobrotus* after abandonment by the birds or through leaching of excess nutrients within the soil profile. These bare areas are often initially very nutrient rich and, in areas where a source of seed is available, they will support a flush of growth of exotic winter annuals such as *Avena*, *Hordeum* and *Bromus* spp., together with thistles and other Asteraceae. Such species are able to utilise the nutrients during the wet months and have set seed and died back by summer, when the likelihood of drought and nutrient toxicity becomes a problem for the less aggressive perennial native species.

Gillham (1965) considered that fire constituted a major cause of rookery depletion and cited altered levels of soil organic content in previously occupied sites after fire as evidence of this effect. Similar areas of "hard ground" were observed in parts of the present study areas and also, more extensively, in the commercial rookery areas on Great Dog Island (MJB, pers. obs.). The intensity and frequency of burning are known to be responsible for organic matter depletion in other Tasmanian ecosystems (e.g. Bowman *et al.* 1986). Fires may also kill the birds directly or cause abandonment of the sites, and may subsequently result in collapse of the system, since it is the birds which are responsible for the organic matter incorporation in the first place.

Thus, the succession in the rookery sites studied is strongly under the control of the birds themselves, but there is a pronounced effect also from human sources especially via fire or introduced weeds, as well as direct exploitation and physical destruction of burrows.

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A DIVERSE HOLOCENE MOLLUSCAN FAUNA, INCLUDING *ANADARA TRAPEZIA*, FROM ROYAL PARK, LAUNCESTON, TASMANIA

by A. Goede, C.V. Murray-Wallace and E. Turner

(with three tables and two text-figures)

GOEDE, A., MURRAY-WALLACE, C.V. & TURNER, E., 1993 (31:viii): A diverse Holocene molluscan fauna, including *Anadara trapezia*, from Royal Park, Launceston, Tasmania. *Pap. Proc. R. Soc. Tasm.* 127: 17–22. ISSN 0080–4703. Department of Geography and Environmental Studies, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001 (AG); Department of Geology, University of Wollongong, Wollongong, NSW 2522 (CM-W); and Tasmanian Museum and Art Gallery, GPO Box 1164M, Hobart, Tasmania 7001 (ET).

Estuarine sediments exposed during road construction at Royal Park in the City of Launceston, northern Tasmania, were found to contain a diverse molluscan fauna with some 40 species identified. An unusual occurrence was the presence of six specimens of *Anadara trapezia*, a species not previously encountered *in situ* in Quaternary marine or estuarine deposits in Tasmania. Amino acid racemisation and electron spin resonance, calibrated against radiocarbon dating, point to a late Holocene age for this estuarine sequence. A numeric age of 2600 ± 400 yrs BP was derived for a specimen of *A. trapezia*, based on the extent of leucine and valine racemisation. Electron spin resonance data are consistent with this age assessment. The presence of *A. trapezia* in late Holocene sediments at Launceston may imply slightly warmer water temperatures during the late Holocene.

Key Words: Holocene, estuarine molluscs, amino acid racemisation, electron spin resonance, Tasmania.

INTRODUCTION

The shell bed was discovered during excavations for the Wellington Street overpass and drawn to the attention of the Queen Victoria Museum and Art Gallery by the site engineer (fig. 1). The material was collected by Mr Ron Kershaw and Dr Bob Green, in or about 1980, and lodged with the Museum collections.

A note with the collection stated that the material was recovered c. 3.6 m below the surface during excavations for the extension overpass. There is no stratigraphic description, but a significant amount of shelly sand matrix was collected. No record was kept of the overlying sediments, and it is not known to what extent they represent estuarine infilling or urban landfill.

The discovery was recorded by Van de Geer (1981), who tentatively suggested a Pleistocene age. He pointed out that *Anadara trapezia* has never been recorded from Holocene marine deposits in Tasmania, but is widely reported from coastal deposits of Last Interglacial age in the southern mainland states of Australia (Ludbrook 1984), in contrast with a more restricted geographic coverage reported from the site, if natural, also appeared consistent with a late Pleistocene age, based on geomorphological reasoning and known rates of estuarine sedimentation.

R.C. Kershaw (pers. comm., 1988) indicated that the site was at the outer edge of the existing floodplain of the Tamar River, and that the bank sloped steeply upwards from this position (fig. 2). The site was reported to be 40 m northwest from the northwest corner of the Supreme Court building and 225 m due east of the Tamar Estuary (grid ref. 511050mE, 5412565mN). The surface of the site was less than 1 m above high tide level and is known to have been subject to flooding during historical times.

A full description of the species content is given, together with an account of the palaeoecological conditions. Two Quaternary dating techniques calibrated against the

radiocarbon method were also applied to specimens of *Anadara trapezia* and *Kateleysia rhytiphora* from this deposit. These dating methods have previously been applied to several other Tasmanian Quaternary coastal fossil shell localities (Murray-Wallace & Goede 1991).

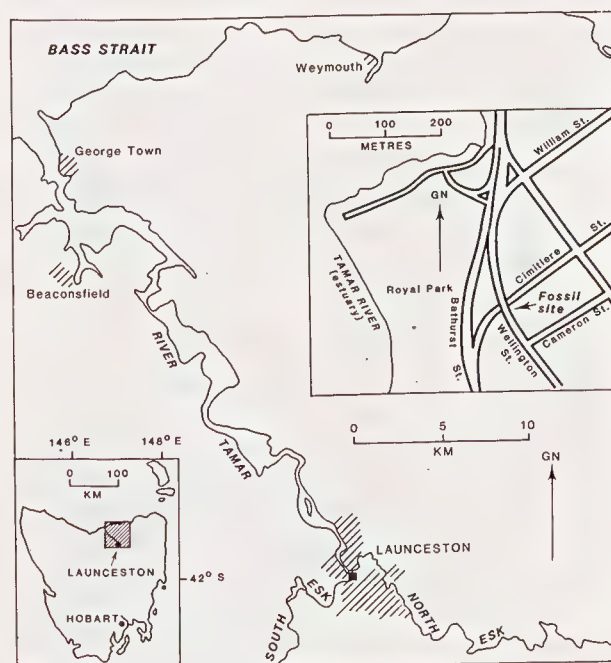


FIG. 1 — Locality map of Launceston area with inset map showing position of fossil site.

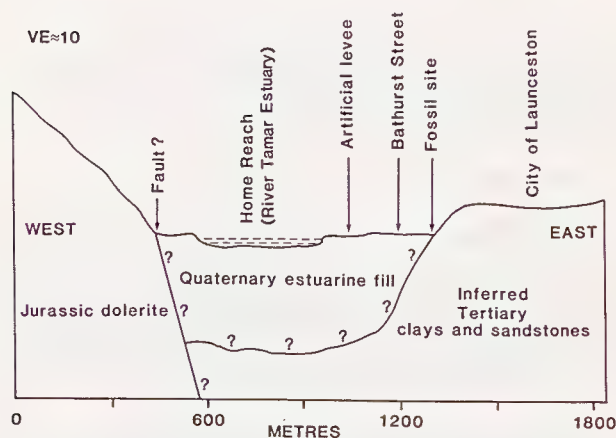


FIG. 2 — Cross-sectional diagram showing relationships of site to topography and geological substrate.

SEDIMENT CHARACTERISTICS

The host sediment is represented by poorly sorted, pale orange-brown quartz sands of mixed fluvial and marine provenance. Grain size ranges from very fine to medium sand size, and the sediment comprises a heterogeneous mixture of coarser-grained, subrounded quartz grains, with frosted surfaces, and finer-grained, angular quartz, with either a vitreous lustre or milky surfaces. Approximately 3% of the sediment consists of coarse (c. 2 mm long axis) shell fragments of unrecognisable affinity and a few prismatic grains of mica. Some micro-gastropods are also present.

SPECIES COMPOSITION AND ECOLOGY

The diverse molluscan fauna recovered from the site is listed in table 1. Some species are represented only by a few fragments, the majority by one to six specimens, while only five species were abundant: *Bittium granarium*, *Diala lauta*, *Batillaria australis*, *Katelysia scalarina* and *K. rhytiphora*.

The fossil assemblage indicates that during deposition the site represented a marginal marine environment characterised by tidal sand and mudflats. A beach may have been present.

Virtually all species are consistent with Holocene and modern populations found in similar environments in Tasmania. An exception is *Anadara trapezia*. Living specimens have not been recorded from Tasmanian waters, although shells are occasionally found washed up on beaches (Sutherland & Kershaw 1971).

Ecological preferences of species are also shown in table 1. The majority are tidal sand or mudflat dwellers, which either browse or filter-feed on the sandy floor or burrow just below the surface of the sand. They are typical of species which prefer quiet, sandy, sheltered bays, inlets and estuaries. Such environments are usually dominated by bivalves, but several gastropods are also found browsing on seagrass or scavenging around tidal sand and mudflats. The presence of littorinid and trochid species indicates that the immediate area was partially rocky, with associated rockpools. Other species present may live on rocks, on algae, in crevices or under rocks. Mudflats are indicated by the presence of some species (*Batillaria australis*, *Nassarius* spp., *Anadara trapezia* and *Spisula trigonella*) and are the only indication of a freshwater influence.

TABLE 1
Species list of subfossil shells from Royal Park, Launceston, and their ecological preferences

Taxon	Ecological Preference
GASTROPODA	
<i>Alaba monile</i> (A. Adams, 1862)	algae, sea grass
<i>Astralium (Micrastraea) aurea</i> (Jonas, 1844)	on rocks
<i>Batillaria lawleyanum</i> (Crosse, 1863)	mud
<i>B. australis</i> (Quoy and Gaimard, 1834)	mud
<i>Bembicium auratum</i> (Quoy and Gaimard, 1834)	on rocks
<i>B. melanostoma</i> (Gmelin, 1791)	on rocks
<i>Bittium granarium</i> (Kiener, 1842)	sand, weed
<i>Bulla quoyi</i> (Gray, 1827)	sand, mud, weed
(syn. <i>Bullaria botanica</i>)	
<i>Cominella eburnea</i> (Reeve, 1846)	sand, rockpools
<i>C. lineolata</i> (Lamarck, 1809)	sand, rockpools
<i>Conuber conicus</i> (Lamarck, 1822)	sand, mud
<i>Dentimitrella tayloriana</i> (Reeve, 1859)	under rocks at low water
<i>Dentimitrella</i> sp. (fragment)	under rocks at low water
<i>Diala lauta</i> (A. Adams, 1862)	algae, sea grass
<i>Gibbula (Cantharidella) tiberiana</i> (Crosse, 1863)	algae, sea grass
<i>Monodonta (Austrocochlea) constricta zebra</i> (Menke, 1829)	sea grass
<i>Nassarius burchardi</i> (Philippi, 1851)	sand, mud
<i>N. nigellus</i> (Reeve, 1854)	sand, mud
<i>N. pauperatus</i> (Lamarck, 1822)	sand, mud
<i>N. pyrrhus</i> (Menke, 1843)	sand, mud
<i>Phasionella</i> sp.	algae
<i>Pleuroploca australasia</i> (Perry, 1811)	sand
<i>Salinator</i> sp.	sand, mud
<i>Seila</i> sp. (probably <i>S. insignis</i> (May, 1911))	deep water
<i>Zeacumantus diemenensis</i> (Quoy and Gaimard, 1934)	sand, mud, weed
BIVALVIA	
<i>Anadara trapezia</i> (Deshayes, 1840)	mud
<i>Eumarcia fumigata</i> (Sowerby, 1853)	sand, sandy mud
<i>Fulvia tenuicostata</i> (Lamarck, 1819)	sand, mud
<i>Irus crenatus</i> (Lamarck, 1818)	on rocks, in cavities
<i>Katelysia rhytiphora</i> Lamy, 1937	sand, mud
<i>K. scalarina</i> (Lamarck, 1818)	sand, sandy mud
<i>Notolepton</i> sp.	algae, sea grass
<i>Ostrea angasi</i> Sowerby, 1871	on rocks, sand, mud
<i>Sanguinolaria biradiata</i> (Wood, 1815)	sand
<i>Spisula trigonella</i> (Lamarck, 1818)	sand, sandy mud
<i>Tawera</i> sp. (fragments)	sand
<i>Tellina deltoidalis</i> Lamarck, 1818	sandy mud
<i>T. mariae</i> Tenison Woods, 1876	sand
<i>Venerupis anomala</i> (Lamarck, 1818)	gravelly sand
(syn. <i>Pullastra fabagella</i>)	
<i>Wallucina assimilis</i> (Angas, 1867)	sand

Four species are essentially estuarine on the basis of the definitions used by Wells (1984). In addition, *Bembicium melanostoma* should also be regarded as such in a Tasmanian context (R.C. Kershaw, pers. comm.). The remaining 34 species are adapted to the marine aspect of the estuarine biota. Many were recorded by Kershaw (1958) as intertidal species at Kelso and Greens Beach, close to the estuary mouth. The present distribution of this fauna indicates a

downstream shift of some 40 km in the marine-dominated estuarine environment, subsequent to the accumulation of the Royal Park sediments.

European settlement is certain to have changed the area beyond all recognition, due to land reclamation and filling, dredging, accelerated erosion in the catchments of the South Esk and North Esk Rivers, agricultural drainage, stormwater run-off and the introduction of new species of plants and animals.

METHODS

Amino acid racemisation (AAR)

This method involves analysis of the amino acid content of the shells. Amino acids persist for lengthy periods after death but undergo structural and chemical changes, which are predominantly a function of the diagenetic temperature history and other time-dependent parameters.

In the protein of all living organisms, amino acids occur almost exclusively in the L (laevo rotatory or left-handed) configuration. This is due to a variety of enzymic reactions, which prevent the development of D-amino acids during life. However, following the death of an organism, these enzymic reactions cease, and amino acids undergo a slow change to the D (dextro rotatory or right-handed) configuration until equilibrium (i.e. 50:50 mixture of L- and D-amino acids). This change is known as racemisation. Dating requires measurement of the D/L ratio, which is determined by gas chromatography. The higher the D/L ratio, the greater the age of a fossil. Advantages of the method include the wide timespan it serves and the fact that small samples (<1 g) may be analysed. Analytical techniques and sampling strategies are described by Kimber & Griffin (1987) and by Murray-Wallace & Kimber (1987). Analyses are reported for several enantiomeric amino acids that include valine (VAL), leucine (LEU), proline (PRO), aspartic acid (ASP), phenylalanine (PHE) and glutamic acid (GLU). Isoleucine results are not reported here because of poor baseline resolution during chromatography.

Electron Spin Resonance (ESR)

This method is based on the fact that many natural materials, of either mineral or biological origin, tend to accumulate radiation defects over time. Dating requires the measurement of concentrations of ionised particles that build up in different kinds of traps within the crystalline lattice of the material. The radiation dose has two components. An internal dose is generated by the presence of radioactive isotopes within the sample (mainly U, Th and K). The external dose is due predominantly to radioactive impurities in the immediate environment of the sample, predominantly within 300 mm radius, with a small contribution from cosmic radiation.

The absorbed radiation dose or gamma equivalent dose (ED) is measured in gray (Gy) and can be determined using an ESR spectrometer. Details of the technique and of the sample preparation procedures can be found in Goede & Hitchman (1987) and Goede (1989). Approximately 10 g of material is required for analysis.

If both the internal and external annual dose rate are determined, it is possible to obtain a numerical age since

$$\text{Age} = \text{ED} / \text{annual dose rate}$$

In practice, numerical estimates involve several assumptions which cannot be verified, and it has been argued that the method is better suited as a relative dating method (Goede 1988); this approach is followed here.

DATING

Amino Acid Racemisation

Parts of the hinge region of a single shell of *Anadara trapezia* were used to assess the extent of AAR. Analytical results are shown in table 2 and compared with analyses from two other Tasmanian Holocene shell sites. The latter have also been dated, using radiocarbon methods (Murray-Wallace & Goede 1991). The Royal Park amino acid data are also compared with modern and Last Interglacial (c. 125 000 yrs BP) specimens of *A. trapezia* from southern mainland states of Australia.

Comparison of these results indicates clearly that the *Anadara* sample from Royal Park is of late Holocene age (i.e. <6000 yrs BP by analogy with the radiocarbon dated samples [table 2]). Most of the amino acids in the sample show significantly lower D/L ratios than samples from the other two Holocene sites and therefore imply a Holocene age for the specimen of *A. trapezia* (table 2).

Similarly, the extent of racemisation of amino acids in the Last Interglacial specimens of *A. trapezia* from South Australia and in the modern sample from Quarantine Bay in southern New South Wales, effectively bracket the Royal Park data, and show conclusively that the *Anadara* from Royal Park is not Last Interglacial in age.

A numerical age assessment for the *Anadara* specimen from Royal Park was undertaken, using the integrated rate expression for racemisation (Schroeder & Bada 1976). Radiocarbon-dated specimens of *Glycymeris* (*Tucetilla*) *striatularis* (6100 ± 180 cal BP: SUA-2833) from Shell Pitts Point in northwestern Tasmania (Murray-Wallace and Goede 1991) were used as a framework to calibrate the amino acid data for the Royal Park *Anadara*. An empirically derived racemisation rate constant (k) of 1.16×10^{-5} was determined on this basis and a numerical age of 2600 ± 400 yrs BP is indicated for the *Anadara* specimen from Royal Park. The numerical age assessment is based on the extent of leucine and valine racemisation.

Electron Spin Resonance

Attempts were made to analyse two shell samples, one consisting of two valves of *Anadara trapezia* and another of three valves of *Katelysia rhytiphora*. It proved to be impossible to obtain an ED value for *Anadara*, as analysis did not yield a characteristic ESR aragonite spectrum. Remains of a third *Anadara* shell, partly used for AAR analysis, were examined by X-ray diffraction, and the material was found to be aragonite. The unusual spectrum of the *Anadara* ESR sample remains unexplained.

Excellent results were obtained for *Katelysia rhytiphora*. An ED value of 5.3 Gy was determined with 95% confidence limits of 1.9 and 8.8. In table 3 this value is compared with ED values obtained for nine samples drawn from four other Tasmanian sites. The ED value is significantly lower than those for three of the other Tasmanian sites, including the Shell Pitts Point and The Spit sites, both radiocarbon dated with calculated ages of c. 6500 yrs BP. The Royal

TABLE 2
Extent of amino acid racemisation ("total acid hydrolysate") in Holocene mollusca from Tasmania, compared with modern and late Pleistocene specimens of *Anadara trapezia* from the southern mainland states of Australia

Locality	Species	Lab code	Conventional age (BP)	Calibrated age (cal BP)*	Amino acid D/L ratio					
					VAL	LEU	PRO	ASP	PHE	GLU
Quarantine Bay, southern NSW	<i>Anadara trapezia</i>	–	(modern)	–	0.02	0.03	–	0.11	–	0.08
Royal Park, Launceston	<i>Anadara trapezia</i>	–	–	–	0.04 ± 0.003	0.07 ± 0.03	0.05 ± 0.005	0.17 ± 0.001	0.11 ± 0.002	0.05 ± 0.002
“The Spit”, Ralphs Bay	<i>Kateleyia scalarina</i>	SUA-2294R	6150 ± 60	6580 ± 160	0.05 ± 0.002	0.14 ± 0.02	0.18 ± 0.01	0.28 ± 0.001	0.11 ± 0.001	0.09 ± 0.006
“The Spit”, Ralphs Bay	<i>Fulvia tenuicostata</i>	SUA-2294R	6150 ± 60	6580 ± 160	0.11 ± 0.01	0.16 ± 0.01	0.11 ± 0.01	0.19 ± 0.01	0.12 ± 0.02	0.11 ± 0.01
Shell Pits Point, NW Tasmania	<i>Glycymeris (Tucetilla) striatularis</i>	SUA-2833	5700 ± 70	6100 ± 180	0.09 ± 0.01	0.17 ± 0.01	–	0.33 ± 0.01(?)	0.16 ± 0.05	0.15 ± 0.01
Woakwine Range, (lagoon facies) Robe SA	<i>Anadara trapezia</i>		(late Pleistocene; c. 125 000 yrs BP)		0.20 ± 0.01	0.35 ± 0.01	–	0.47 ± 0.003	0.42 ± 0.01	0.32 ± 0.01

* Calibrated radiocarbon ages (cal BP) include a correction for the marine reservoir effect for southern Australian coastal waters. This involved the subtraction of 450 ± 35 years from the conventional radiocarbon age (Libby half-life of 5568 years) according to the principles outlined by Gillespie & Polach (1979). Radiocarbon calibration is after Stuiver *et al.* (1986).

TABLE 3
Summary of ESR analytical data on Holocene molluscan shells from Tasmanian deposits

Sample No.	Species	ED (Gy)	95% conf. limits
Royal Park, Launceston			
T20	<i>Katelysia rhytiphora</i>	5.3	1.9–8.8
Shells Pits Point, NW Tasmania			
T10	<i>Fulvia tenuicostata</i>	26	21–30
T16	<i>Katelysia rhytiphora</i>	18	14–21
Perkins Island, NW Tasmania			
T7	<i>Fulvia tenuicostata</i>	20	16–24
T12	<i>Glycymeris (T)</i> <i>striatularis</i>	15	10–20
The Spit, Ralphs Bay			
T15	<i>Katelysia scalarina</i>	13	10–16
F74 (1)	<i>Fulvia tenuicostata</i>	19	16–22
F79 (1)	<i>Katelysia scalarina</i>	13	12–15
Shelly Beach, Ralphs Bay			
F68 (1)	<i>Fulvia tenuicostata</i>	6.4	4.6–8.2
F68 (2)	<i>Fulvia tenuicostata</i>	10	8–13

Park ED value is comparable to two ED values obtained at Shelly Beach, South Arm Peninsula, for *Fulvia tenuicostata*. This site has a radiocarbon age of 2930 ± 80 cal BP (SUA-2293). Thus, the Royal Park sample appears to be of similar age. This is in good agreement with the age estimated by AAR. A z-score test indicates that the AAR derived age is not significantly different to this radiocarbon age ($z = 0.809$).

DISCUSSION

In Australia, including Tasmania, sea levels appear to have reached their present height c. 6500 $\pm$ 250 yrs BP (^{14}C) (Thom & Roy 1985). However, arguments continue concerning the extent of sea-level fluctuations since that time (Hopley 1983, Nakada & Lambeck 1989). Infilling of the Tamar Estuary must have proceeded continuously since that time. It is interesting to note that nearly 4000 years later the marine influence at Royal Park, near the head of the estuary, remained strong, suggesting that estuarine infilling that occurred up to this time had little impact on the ecology. This is believed to reflect low rates of natural denudation in the catchments of the South Esk and North Esk Rivers. The situation may well have continued until historical times.

Today, many of the shell species collected at Royal Park appear to be absent from this section of the modern estuary. Rapid siltation has become a major environmental problem (Foster *et al.* 1986). It has been estimated by Skirving (1989) that, under present-day conditions, the average annual input of suspended sediment into the Tamar Estuary is 56 900 tonnes/year. The bulk of this can be attributed to accelerated erosion due to forestry, mining, farming and road construction activities.

Estuarine silting has been further accelerated by the introduction of the saltmarsh grass *Spartina anglica* into the

Tamar Estuary in 1947. It has very successfully colonised the upper third of the intertidal slope in most of the area. Before 1947, this area had been almost completely bare of vegetation. The saltmarsh grass has proved extremely efficient at promoting and stabilising deposition of silt (Phillips 1975, Pringle 1982).

An unusual feature of the site is the occurrence of the bivalve *Anadara trapezia*. This species has not been recorded *in situ* from any Quaternary marine, estuarine or beach deposits in mainland Tasmania or in the Bass Strait Islands (Colhoun *et al.* 1982, Jennings 1959, Sutherland & Kershaw 1971) nor has it been recorded live from Tasmanian coastal waters in historical times, but occasionally shells are washed up on Tasmanian beaches. Sutherland & Kershaw (1971) have recorded the presence of shells at Yellow Beach, south-east Flinders Island.

According to Gill (1977), its present southern limit in the southeastern mainland states is at Port Philip Bay, Central Victoria, where it occurs in small numbers and in smaller size compared with the mid-Holocene population. Gill also claimed that it has occurred in northern Tasmania in warmer times but provided no evidence.

Anadara trapezia first migrated into southern Australia some time during the middle Pleistocene, as penultimate interglacial (oxygen isotope stage 7: c. 220 000 yrs BP) occurrences have been dated from Peppermint Grove in the Swan Estuary, Western Australia (Hewgill *et al.* 1983, Murray-Wallace & Kimber 1989) and from Redcliff in northern Spencer Gulf, South Australia (Murray-Wallace *et al.* 1988). A possible older occurrence of the species has been cited by Gill (1977) in the Hopkins River Estuary at Warrnambool. However, relative ESR dating by Goede (1989) has shown that the site contains shell material of more than one age. The *Anadara trapezia* shell analysed from the site was found to be of Last Interglacial age.

If, as inferred by Gill (1977), the southern limit of the distribution of *Anadara trapezia* is controlled by water temperatures, conditions in the Tamar Estuary are likely to have been somewhat warmer than at present at the time of deposition of the Royal Park sediments. Therefore, the absence of *A. trapezia* in the Tamar Estuary may be related to a late Holocene cooling event. The exact sea level at that time is unknown. It was clearly no higher than today and may well have been lower.

CONCLUSION

Amino acid racemisation and ESR dating calibrated against radiocarbon indicate that estuarine sediments at Royal Park are of late Holocene age and are host to the estuarine bivalve *Anadara trapezia*. The variety and composition of molluscan species indicates a strong marine influence in the upper Tamar Estuary 4000 years after it was flooded by the Post-glacial marine transgression. This is also consistent with the nature of the host sediments.

The extremely high siltation rates observed at the present time are believed to reflect the combined effects of accelerated erosion of the catchment and the introduction of the saltmarsh grass *Spartina anglica*. The presence of *Anadara trapezia* is the first Tasmanian record of this species in a stratigraphic context and may well reflect slightly higher water temperatures than prevail today.

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RAINFOREST IN EASTERN TASMANIA — FLORISTICS AND CONSERVATION

by M.G. Neyland and M.J. Brown

(with two tables, four text-figures and one appendix)

NEYLAND, M. G. & BROWN, M. J., 1993 (31:viii): Rainforest in eastern Tasmania — floristics and conservation. *Pap. Proc. R. Soc. Tasm.* 127: 23–32. ISSN 0080-4703. Parks and Wildlife Service, Department of Environment and Land Management, GPO Box 44A, Hobart, Tasmania 7001 (MGN); Forestry Commission, Macquarie Street, Hobart, Tasmania 7000 (MJB).

Six floristic communities are described from rainforest in northern and eastern Tasmania. The communities occur in lower rainfall areas, where they are often restricted to fire-protected sites. They have climatic envelopes which are significantly distinct from each other and from rainforest in higher rainfall areas. The conservation status of the communities is assessed.

Key Words: rainforest, Tasmania, conservation, relicts.

INTRODUCTION

Temperate rainforests worldwide are restricted mainly to the coastal and maritime zones, and generally occur in areas of high rainfall (Kellogg 1992). All the rainforests of Tasmania are relicts of extensive rainforest which once occurred on the ancient continent Gondwana (Hill 1990, Nelson 1981). Many of the genera which are characteristic of rainforest in Tasmania occur also in the warm temperate rainforest facies on the Australian mainland, from which the Tasmanian flora may have been derived (Hill & Read 1987). These genera retain close relatives in other parts of the disintegrated supercontinent, especially New Zealand, New Caledonia and South America (Nelson 1981). Such genera include *Nothofagus*, *Eucryphia*, *Lagarostrobos*, *Phyllocladus*, *Aristotelia*, *Coprosma*, and *Uncinia* (Jarman & Brown 1983). The largest areas of rainforest in Tasmania are in the northwest. In the west and southwest the rainforest is more fragmented and occurs as a mosaic together with scrub and buttongrass moorlands (Jarman *et al.* 1984). Large patches of rainforest also occur in the northeast highlands. Smaller outlying patches of rainforest occur in the drier lowland and eastern highland regions of Tasmania. These outliers are presumed to be leftovers from past periods when the climate was more suited to rainforest (Macphail 1976, 1979). The distribution, composition and ecology of these forests are the subject of this paper.

THE STUDY AREA

The study area was defined using the modified Nature Conservation Regions (NCR) of Orchard (1988). The study area comprises NCR 4a (north coast and hills), 4b (midlands), 7a (east coast and tiers), and 7b (southern midlands). South Bruny Island lies within NCR 10b (south [dolerite]) but was included because its rainforests are considered significant outliers. Two sites in NCR 6 (northeast highlands) are included, as they are lowland sites within low rainfall areas. The southwest portion of NCR 4a was excluded, because the forests in this area are closely related to the western rainforests. Species nomenclature follows Buchanan *et al.* (1989).

METHODS

TASFORHAB profiles (Peters 1984) were collected from relict rainforest patches throughout the study area. These profiles record the floristics, species abundance and the structure of the forest. A number of profiles already on the TASFORHAB data base were used to cross-check results, and to locate potential rainforest sites.

ANALYSIS

The collected data set of 82 profiles was analysed using DECORANA (Hill & Gauch 1980) and TWINSpan (Hill 1979) (fig. 1). A few sites which were clearly misclassified were subsequently manually resorted. The classifications which resulted have been interpreted using the terminology established by Jarman *et al.* (1984).

The climatic profile of each site was determined using BIOCLIM (Busby 1986, Nix 1986). A principal components analysis of the sites was run using the 16 BIOCLIM variables, in order to determine the degree of autocorrelation among the climate variables and to explore the different climates among the sites. The relationships between the selected climate variables and the floristic ordination scores were explored using stepwise regression. Stepwise regression was used in preference to full multiple regression to determine the most parsimonious set of predictor variables.

Discriminant analysis of the floristic groups using the BIOCLIM variables as data vectors was used to further explore the relationship between climate and the floristic groups.

RESULTS

Four floristic groups were identified by the analysis (fig. 1): (1) Callidendrous sassafras–musk rainforest (two communities) (C1.2 and C3.2, Jarman *et al.* 1991); (2) Callidendrous myrtle rainforest (two communities) (C1.1, Jarman *et al.* 1991); (3) Thamnisc sassafras–laurel rainforest (one community) (CT8, Jarman *et al.* 1991); (4) Callidendrous–thamnisc myrtle rainforest (one community) (CT7, Jarman *et al.* 1991). Detailed floristics for these communities are given in the appendix.

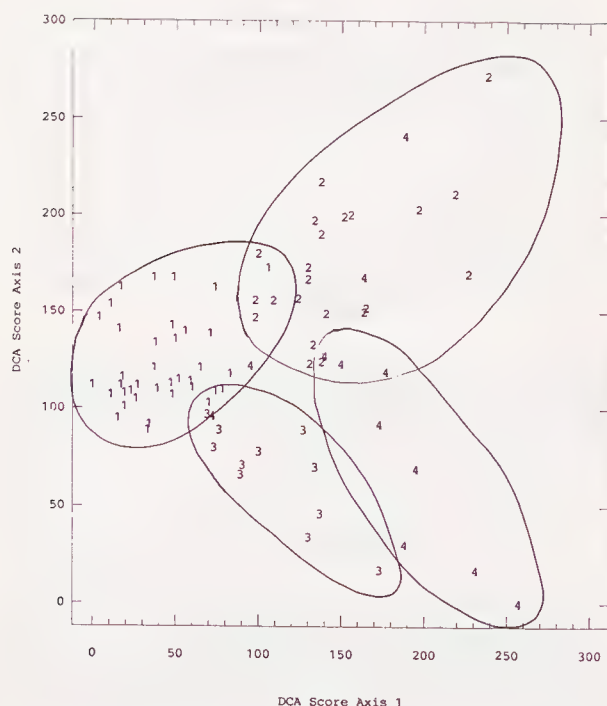


FIG. 1 — Ordination of the floristic data. The labels correspond to the TWINSPAN groups and to the classificatory groups described in the text.

Principal Components Analysis

The first three principal components accounted for 94% of the variation between the sites. Figure 2 is a plot of the rainforest patches on the first two principal component axes, with the points labelled according to the floristic group to which they were assigned following classification of the sites by TWINSPAN. It is clear from the figure that the northeastern sites (callidendrous sassafras rainforest [northeast] and the callidendrous myrtle riverine patches [labelled 1 and 4 respectively in the figure]) are climatically distinct from the other sites.

Regression Analysis

The stepwise regression analysis indicates that rainfall in the driest month and the mean temperature of the coolest month are important factors in predicting the occurrence of the different floristic groups (table 1). Both variables are closely related to the first DCA axis.

Discriminant Analysis

The discriminant analysis clearly separates the rainforest communities into three regional groups (fig. 3):

- a northeast group comprising callidendrous sassafras musk rainforest (northeast) and callidendrous myrtle rainforest (riverine) which occurs only in northeast Tasmania;
- an eastern group comprising callidendrous sassafras musk

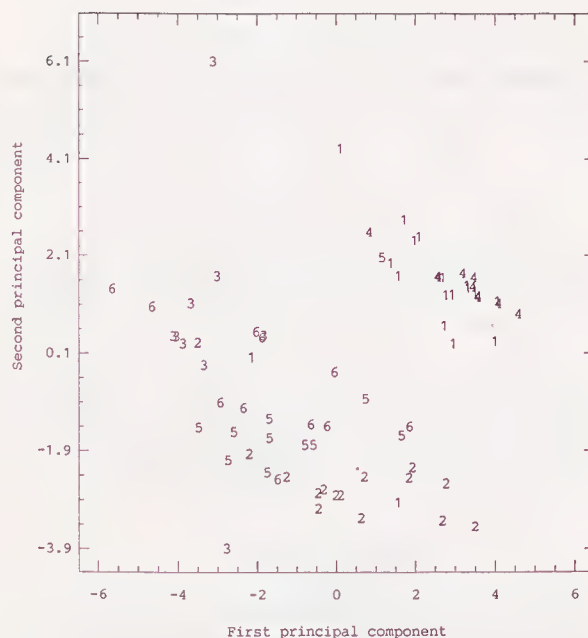


FIG. 2 — Scatterplot of the rainforest patches on the first two principal components axes derived from the principal components analysis of the BIOCLIM data. The labels correspond to the six rainforest communities: (1) Callidendrous sassafras–musk rainforest (north east); (2) Callidendrous sassafras–musk rainforest (eastern highlands); (3) Callidendrous myrtle rainforest (highlands); (4) Callidendrous myrtle rainforest (riverine); (5) Thamnic sassafras–laurel rainforest; (6) Callidendrous–thamnic myrtle rainforest).

rainforest (eastern highlands) and callidendrous myrtle rainforest (highland) which occurs predominantly in eastern Tasmania;

- a southeast group comprising thamnic sassafras–laurel rainforest and callidendrous–thamnic myrtle rainforest. Patches of all of these occur either on the Tasman and Forestier Peninsulas or on Bruny Island.

Clearly the regional climate has a strong influence on the structure and floristics of rainforest in eastern Tasmania. Two of the climatic factors discriminating among the groups are the rainfall of the driest quarter, which has been shown previously (Jackson 1965, Busby 1986) to be an important factor in the distribution of rainforest statewide, and the mean rainfall of the wettest quarter. Overlaid on this are temperature, local topographic and microclimatic effects, which determine the nature of particular rainforest patches at particular sites.

COMMUNITY DESCRIPTIONS

1. Callidendrous sassafras–musk rainforest

Two closely related but distinct facies were defined within this group. One occurs in the northeast of the state, the other is restricted to the eastern highlands. The sassafras–musk rainforests of the northeast have a characteristic “fringe” forest of *Acacia melanoxylon* over a shrubby understorey. They occur at altitudes ranging from 90–400 m a.s.l. and on granite or sedimentary-derived soils. The sassafras–musk rainforests of the eastern highlands lack *A. melanoxylon*; they

TABLE 1
Stepwise regression of the climate variables against the floristic ordination scores

Selection: Forward	Maximum steps: 500	F-to-enter: 4.00	
Control: Manual	Step: 2	F-to-remove: 4.00	
R-squared: 0.44001	Adjusted: 0.42584	MSE: 0.2362	Df: 79
Variables in model	Coefficient	F-Remove	
Mean temperature, coolest month	-27.5742	12.3317	
Rainfall, driest month	3.71691	45.2788	
Variables not in model	P. Corr.	F-Enter	
Annual temperature range	0.0973	0.74	
Temperature, wettest quarter	0.1449	1.67	
Coefficient of variation of rainfall	0.1779	2.54	
Annual rainfall	0.0701	0.38	
Rainfall, coolest quarter	0.0914	0.65	
Temperature warmest quarter	0.0963	0.73	
Temperature coolest quarter	0.1143	1.03	
Rainfall, wettest month	0.1067	0.89	
Temperature, driest quarter	0.1506	1.80	

occur at altitudes ranging from 100–800 m a.s.l., but usually over 400 m, and exclusively on dolerite-derived soils.

Throughout their range both facies are dominated by *Atherosperma moschatum*. The tall pyramidal crowns cast a soft green shade, which harbours a rich epiphytic fern flora on most sites. *Pittosporum bicolor* is an infrequent but widespread small tree, which is nearly always found growing as an epiphyte, either on tree ferns or old logs, as its seedlings are much favoured by browsing animals. *Notelaea ligustrina* is also an infrequent but widespread small tree, which is characteristically festooned with mosses and lichens, notably *Usnea* spp. (old man's beard).

Where the canopy is deep and well formed, the sparse understorey contains scattered ground ferns (*Blechnum watsii*, *Polystichum proliferum*, *Histiopteris incisa*), tree ferns (*Dicksonia antarctica*) and epiphytic ferns. Where the canopy is more broken, the most prominent understorey shrub is *Olearia argophylla*, which also often fringes patches of rainforest. *Olearia argophylla* seedlings are very rare in undisturbed rainforest, but the shrub is very long lived and persists by suckering and layering, and by producing new shoots from windthrown shrubs.

Coprosma quadrifida and *Pimelea drupacea* are common small shrubs. The vines *Parsonsia brownii* and *Clematis aristata* are both widely scattered throughout the range of the community. Tree ferns (*Dicksonia antarctica*) are ubiquitous, forming galleries alongside streams and creeks and being more widely scattered elsewhere. The ground ferns *Blechnum watsii* and *Polystichum proliferum* are also common and widespread. *Histiopteris incisa* is inconspicuous, except in disturbed areas where it may form extensive colonies. Epiphytic ferns range from common to abundant. On drier sites, only the more robust species, such as *Microsorium diversifolium*, *Rumohra adiantiformis* and *Grammitis billardieri*, are prominent, whilst filmy ferns are restricted to the most protected niches, such as the underside of logs and tree ferns. On wetter sites, the epiphytic flora is diverse and luxurious, with all available surfaces clothed with mosses, lichens and/or epiphytic ferns.

The northeast forests are characterised by a fringing forest of *Acacia melanoxylon* over a shrubby understorey containing any of *Pomaderris apetala*, *Olearia argophylla*, *Beyeria viscosa*, *Zieria arborescens*, *Acacia verticillata* and *Olearia lirata*. *Cyathea australis* (prickly tree fern) is also commonly present in this fringing forest. The ground ferns *Allantodia australis* and *Lastreopsis acuminata* are characteristic of this community; both are very rare in the eastern highlands.

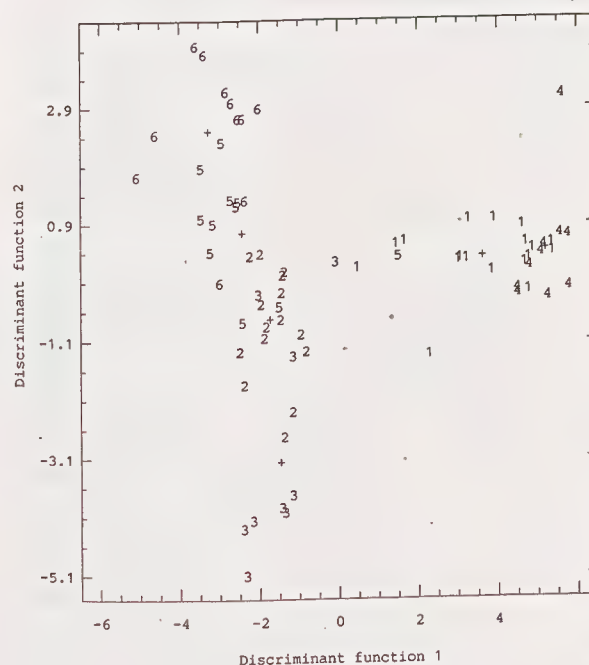


FIG. 3 —Scatterplot of the rainforest patches along the first two discriminant functions. The labels are as for figure 2.

The eastern highlands forests usually grade into wet sclerophyll forests. Fringing forests of *Acacia melanoxylon* do not occur and *Cyathea australis* is very rare. The dolerite-based streams of the eastern highlands have rocky beds, which support the water ferns *Blechnum chambersii*, *B. fluviatile* and *B. patersonii* (usually as widely scattered plants). These species are rare in the northeast forests, where stream beds are mainly composed of fine alluvial material, an unsuitable substrate.

Distribution (figs 4A & B)

This community extends from Mt Walter in the south to the Asbestos Ranges on the central north coast. In most cases it occurs as a narrow (<100 m wide) band, extending along deeply incised streams. It is sporadically more extensive on optimal sites, where it spreads across steep southeast-facing slopes. The community also occurs in the Florentine Valley, where it is found also as an understorey to *Eucalyptus regnans* (Gilbert 1959).

2. Callidendrous Myrtle Rainforest

Two closely related but distinct communities are defined within this group. Highland rainforests occur as extensive (10–75 ha) patches on southeast facing slopes, usually at altitudes of 300–700 m a.s.l. Riverine rainforests occur as long narrow patches extending along streams and rivers, usually at altitudes of less than 300 m. The riverine rainforests have a better developed understorey, particularly on the river banks, where available light levels are higher. The riverine rainforests also have a complement of streamside and floodbank species, which do not occur in the highland forests.

2A. Callidendrous Myrtle Rainforest (highland)

This community is dominated by large trees of *Nothofagus cunninghamii* which, on good sites, may reach 30 m in height. *Atherosperma moschatum* is usually subdominant, although local pure thickets can occur. When present, *Acacia dealbata* and *A. melanoxylon* are locally common and apparently associated with past disturbance. *Pittosporum bicolor* is widespread and uncommon, and is nearly always found growing as an epiphyte on *Dicksonia antarctica*.

When the canopy is closed, the understorey is sparse and open, comprising widely scattered straggling shrubs of *Coprosma quadrifida*, *Aristotelia peduncularis* and *Pimelea drupacea*. Where the canopy is more broken, large spreading shrubs of *Olearia argophylla* are often present. *Bedfordia salicina* and *Pomaderris apetala* are also often present in gaps or in disturbed areas. The latter three species are also prominent on the fringes of rainforest patches. The vine *Clematis aristata* is widespread but uncommon and easily overlooked, as its foliage is carried high in the canopy.

Dicksonia antarctica is widespread and common, particularly along drainage lines where the canopy is more open. *Cyathea australis* occurs sporadically on the margins of the community. The ground ferns *Blechnum wattsii* and *Polystichum proliferum* are widespread and abundant. These two species can form pure or mixed local thickets. In areas where the canopy is particularly dense, the ground ferns may be absent altogether and the ground is carpeted with a layer of myrtle twigs.

Epiphytes are not well developed. Mosses and lichens are widespread but do not attain the luxuriance found in some communities. Epiphytic ferns are scattered throughout the forest but are not conspicuous. *Microsorium diversifolium* is the most prominent of these, often forming large colonies along the larger branches of myrtles.

Disturbed areas or large canopy gaps, caused by windthrow or myrtle wilt, are often colonised by one or more of *Histiopteris incisa*, *Hypolepis rugosula*, *Urtica incisa*, *Hydrocotyle hirta*, *Australina pusilla* and *Gahnia grandis*. Of these, *Histiopteris incisa* is often the most abundant and can form extensive colonies. All of the above species are found in undisturbed rainforest, but generally as widely scattered individuals.

2B. Callidendrous Myrtle Rainforest (riverine)

Where this community is wide enough to extend away from the streambanks, it is similar to the highland form, with large myrtles over an open, park-like understorey. However, the narrowness of many of these patches admits more light than penetrates the more extensive highland patches. As a result, wet sclerophyll species such as *Zieria arborescens*, *Monotoca glauca* and *Olearia lirata* are able to persist beneath the canopy. *Acacia dealbata*, *A. melanoxylon*, *Pomaderris apetala* and *Notelaea ligustrina* are more common in the riverine than in the highland forests. The presence of the first three of these species is often related to past disturbance.

Todea barbara and *Sticherus tener* are found only on stream banks. Floodbanks in streams and rivers often support a diverse and temporary (until the next flood) assemblage of adventive species such as *Carex appressa*, *Juncus* spp., *Cirsium* spp., *Acaena novae-zelandiae* and a variety of small herbaceous species.

Distribution (figs 4C & D)

The community occurs in three main areas. In the Dazzler Ranges (central north coast) between Beaconsfield and Devonport, riverine forests extend along Wallaby Creek, Saxons Creek, Andersons Creek (Holwell Gorge) and the Supply River. In the northeast, riverine forests are found along the Forester and Ringarooma Rivers, and extensively along the Great Musselroe River and its tributaries. A single small highland patch occurs on the upper eastern slopes of Mt Horror. In the east, the community is found in the Douglas–Apsley region, mostly as disjunct highland patches; a few small patches of riverine forest are found along the Douglas River and its tributaries. Closely related forests are common in northwestern and western Tasmania, generally on more fertile, low-altitude sites (Jarman *et al.* 1984).

3. Thamnic Sassafras–Laurel Rainforest

Floristically this community is closely related to callidendrous sassafras–musk rainforest. Structurally, however, it is quite distinct. *Atherosperma moschatum* again dominates the canopy, but the trees are shorter, often with dead tops, and the canopy is more broken. *Pittosporum bicolor*, *Pomaderris apetala* and *Notelaea ligustrina* are all infrequently present as small trees. *Phyllocladus aspleniifolius* is dominant in two small patches, on Prossers Sugarloaf near Orford and near Bishop and Clerk on Maria Island. Elsewhere it is rare or absent. Beneath the broken canopy, the understorey development is greater than in the callidendrous sassafras–musk rainforests of the east and northeast.

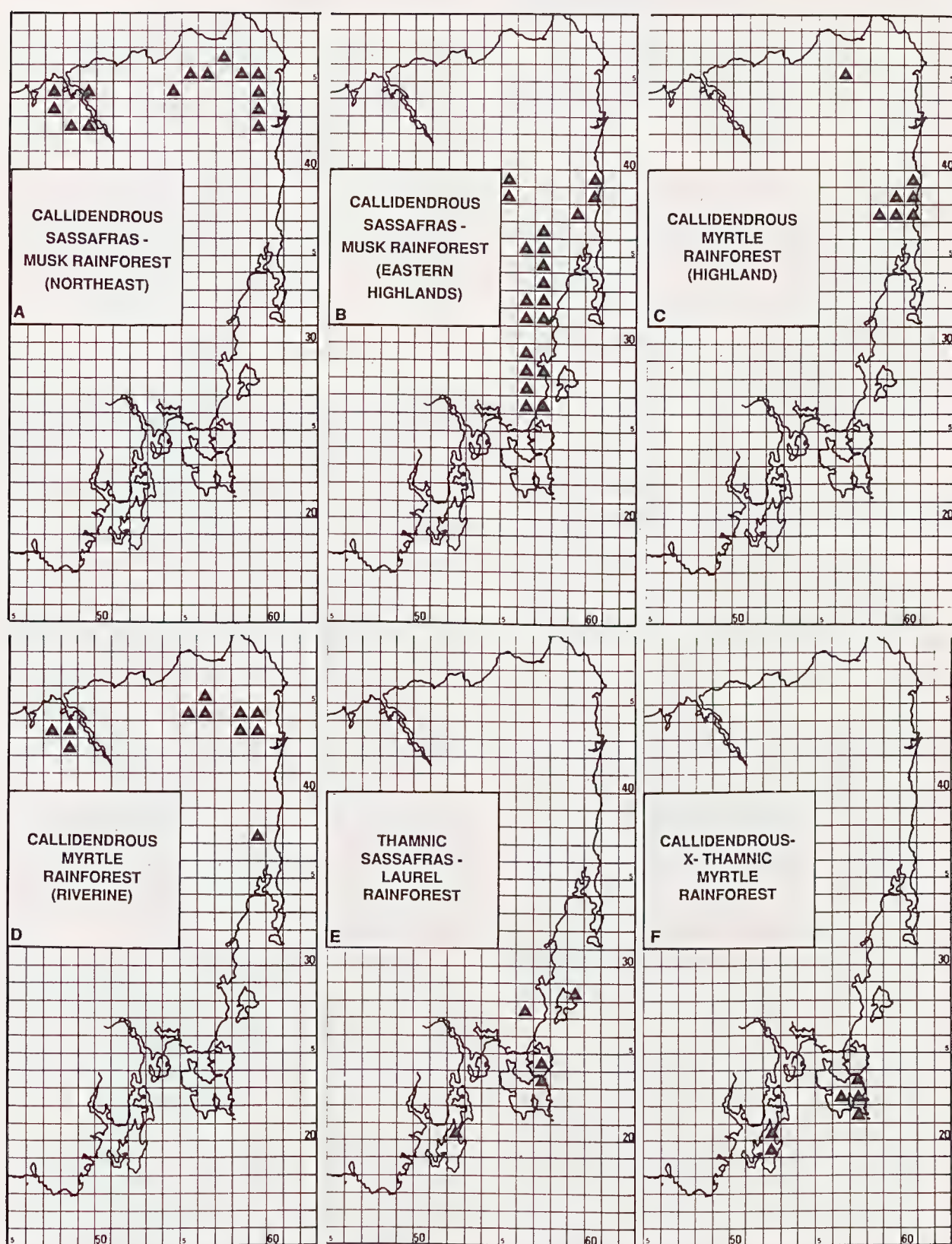


FIG. 4 — The distribution of (A) callidendrous sassafras–musk rainforest (northeast); (B) callidendrous sassafras–musk rainforest (eastern highlands); (C) callidendrous myrtle rainforest (highland); (D) callidendrous myrtle rainforest (riverine); (E) thamnic sassafras–laurel rainforest; (F) callidendrous–thamnic myrtle rainforest.

Olearia argophylla and *Anopterus glandulosus* dominate the understorey, both forming dense local thickets in places. A variety of other shrubs is also present, usually as scattered plants, including *Cyathodes glauca*, *Pomaderris apetala*, *Coprosma quadrifida*, *Tasmannia lanceolata* and *Pimelea drupacea*. *Dicksonia antarctica* is common, and the ground ferns *Blechnum watsii* and *Polystichum proliferum* are abundant.

The epiphytic flora of this community is luxurious and dominated by moss. Epiphytic ferns are widespread but scattered and never reach the abundance found in the callidendrous sassafras–musk rainforests. Lichens are similarly widespread but scattered, with the exception of the crustose species which are ubiquitous on smooth-barked tree trunks. Mosses in this community are exceptionally well developed, a multihued carpet of green covering most surfaces up to about 2 m above ground level, with some mosses extending higher into the canopy. The abundance of mosses of varying shades of green and the relatively high light levels are the distinguishing characteristics of the community.

Distribution (fig. 4E)

This community extends from Bruny Island (a single small patch) in the south to Maria Island in the east, with a notable outlier on Prossers Sugarloaf. It generally occurs at altitudes between 300 and 550 m a.s.l., and is found only on moderate to steep southeast-facing slopes. The stronghold of the community is the Forestier Peninsula, where there are a number of patches, including one of more than 100 ha. The community is not known from outside the study area.

4. Callidendrous–Thamnic Myrtle Rainforest

The myrtle dominated rainforests of Bruny Island and the Tasman Peninsula are very diverse, with considerable local structural and floristic variation. Much of this variation is related to past disturbance. Rather than attempt to describe all the variation observed, the communities have been pooled on the basis of their dominant floristics.

The forests are generally dominated by *Nothofagus cunninghamii*. With rare exceptions the dominants are of poor form, with major limbs missing and some dieback generally evident in the crown. Where the dominants are of good form, the forest is open and park-like, with a sparse understorey of *Blechnum watsii*. More commonly, the understorey is dense and diverse, and progress through it is very slow.

Anopterus glandulosus (native laurel) dominates the understorey on both Bruny Island and the Tasman Peninsula, and forms impenetrable local thickets, over a ground layer dominated by *Blechnum watsii*. On Bruny Island, *Anodopetalum biglandulosum* (horizontal) and *Gahnia grandis* fill most of the gaps not occupied by *Anopterus glandulosus*, with a variety of smaller shrubs such as *Olearia persoonioides*, *Richea dracophylla* and *Cyathodes glauca* crammed into any leftover space. *Anodopetalum biglandulosum* does not occur on the Tasman Peninsula — the understorey of these forests is still thick but progress through them is possible. *Dicksonia antarctica* is more prominent in the peninsula forests than on Bruny Island.

With the exception of crustose lichens, which are widespread and abundant on smooth-barked trees, epiphytes are poorly developed in these forests. Mossy banks are rarely encountered in local canopy gaps. Epiphytic ferns are very

scattered, although they may be locally common on preferred sites.

Distribution (fig. 4F)

This community is quite widely distributed on Bruny Island, extending from Simpsons Creek south along the South Bruny Range to Mt Bruny. On the Tasman Peninsula the community is less common, small isolated patches occurring on the eastern side of the peninsula between Plateau Road and Mt Fortescue, with two small outliers on Mt Arthur and Mt Clark. The altitude range of the community is from 50–500 m a.s.l., and it is found on moderate to steep south to northeast facing slopes. The community is also found in small scattered patches in southwestern Tasmania (Jarman *et al.* 1984).

DISCUSSION

Cool temperate rainforest reaches its greatest Australian extent in Tasmania, with only restricted occurrences on the mainland (Howard & Ashton 1973, Jarman *et al.* 1991). It is generally restricted to areas where the annual rainfall exceeds 1000 mm and the rainfall in summer is greater than 50 mm per month (Jackson 1965). The climatic profile of *Nothofagus*-dominated rainforest has been defined by Busby (1986) as a minimum annual rainfall of 930 mm (range 930–3500 mm), with precipitation in the driest month exceeding 50 mm. Throughout the study area, the climate is marginal for the survival of rainforest, with rainfall in the range 850–1150 mm and summer droughts being common (Jackson 1988). The presence and survival of the eastern outlying rainforest patches is therefore largely dependent on the relationship between climate, topography and altitude.

In the north, northeast and southeast, rainforest patches occur in fire-shadow sites, i.e. in relatively moist sites which are protected from fire either by physical barriers, such as rivers or block or boulder scree, or by topographic influences such as marked changes in slope or aspect. Patches also occur on steep southeast-facing slopes where the degree of insolation is markedly reduced, especially in winter, and where moisture availability remains high except in the most extreme conditions.

In the east, where the average rainfall is less than 800 mm per annum and the climate is least favourable for rainforest, the rainforest patches are restricted to steep southeast-facing slopes. Increasing altitude reduces the amount of topographic protection patches require, because of cooler ambient temperatures and fog precipitation or cloud trapping at higher altitudes, and consequent stripping of moisture by the vegetation.

Similar rainforest to that described above has also been recorded from Victoria. Howard & Ashton (1973) described *Nothofagus cunninghamii* dominated forest from the Central Highlands, the Otway Ranges and the Strzelecki–Wilsons Promontory areas. In all areas, the *Nothofagus*-dominated forests occupy similar niches to those occupied by similar forests in Tasmania, that is, fire-protected riverine sites or deep gullies. Their structural type, “tall closed forest”, is closely related to callidendrous myrtle rainforest, with the presence of *Hedycarya angustifolia* (a small tree) being the only significant difference. Forbes *et al.* (1981) have described cool temperate rainforest from eastern Gippsland which is structurally and floristically very similar to callidendrous

TABLE 2
Percentage frequencies of species by classificatory groups

Species*	Floristic group†					
	1A	1B	2A	2B	3	4
<i>Lastreopsis acuminata</i>	32	0	0	0	0	0
<i>Allantodia australe</i>	26	0	0	0	0	0
<i>Asplenium bulbiferum</i>	32	22	0	0	0	25
<i>Acacia dealbata</i>	11	28	60	89	0	0
<i>Blechnum chambersii</i>	0	28	10	11	0	0
<i>Beyeria viscosa</i>	0	61	2	22	8	0
<i>Urtica incisa</i>	37	22	30	0	17	8
<i>Parsonsia straminea</i>	63	44	10	11	8	33
<i>Acacia melanoxylon</i>	68	0	80	22	8	33
<i>Zieria arborescens</i>	37	33	40	0	8	8
<i>Hydrocotyle hirta</i>	26	67	20	11	58	0
<i>Asplenium terrestre</i>	42	67	30	44	50	8
<i>Blechnum nudum</i>	47	17	90	22	17	8
<i>Monotoca glauca</i>	16	0	50	0	17	17
<i>Polyphlebium venosum</i>	89	67	70	22	50	17
<i>Olearia argophylla</i>	84	100	40	89	75	75
<i>Hymenophyllum cupressiforme</i>	68	78	60	89	67	8
<i>Notelaea ligustrina</i>	42	50	60	44	58	50
<i>Pomaderris apetala</i>	58	39	60	44	83	33
<i>Ctenopteris heterophylla</i>	37	89	10	2	67	42
<i>Hypolepis rugosula</i>	58	72	40	44	50	42
<i>Hymenophyllum australe</i>	68	56	30	11	83	67
<i>Histiopteris incisa</i>	89	72	70	89	75	58
<i>Pimelea drupacea</i>	58	78	30	56	75	33
<i>Microsorium diversifolium</i>	95	94	100	67	92	75
<i>Polystichum proliferum</i>	84	89	70	89	92	67
<i>Rumohra adiantiformis</i>	95	78	60	33	92	83
<i>Hymenophyllum flabellatum</i>	89	78	100	67	100	42
<i>Dicksonia antarctica</i>	100	100	100	100	100	100
<i>Atherosperma moschatum</i>	100	100	100	100	100	100
<i>Blechnum wattsii</i>	89	72	100	100	75	100
<i>Pittosporum bicolor</i>	84	94	90	100	83	92
<i>Coprosma quadrifida</i>	89	78	90	33	100	58
<i>Tmesipteris billardieri</i>	79	28	70	78	100	42
<i>Grammitis billardieri</i>	58	83	50	78	100	75
<i>Hymenophyllum rarum</i>	68	78	40	56	100	67
<i>Aristotelia peduncularis</i>	32	28	30	35	33	67
<i>Clematis aristata</i>	37	61	10	44	75	33
<i>Gahnia grandis</i>	21	11	30	56	25	33
<i>Tasmania lanceolata</i>	26	17	40	44	75	75
<i>Drymophila cyanocarpa</i>	5	17	20	33	25	33
<i>Nothofagus cunninghamii</i>	0	0	100	100	0	100
<i>Hymenophyllum peltatum</i>	5	22	0	67	8	50
<i>Sticherus tener</i>	5	0	50	0	0	42
<i>Todea barbara</i>	0	0	0	40	0	0
<i>Bedfordia salicina</i>	5	11	0	67	8	8
<i>Cyathodes glauca</i>	5	22	0	0	75	50
<i>Anopterus glandulosus</i>	0	0	0	0	100	25
<i>Phyllocladus aspleniifolius</i>	0	0	0	0	33	42
<i>Richea dracophylla</i>	0	0	0	0	17	25
<i>Gaultheria hispida</i>	0	0	0	0	8	42
<i>Cenarrhenes nitida</i>	0	0	0	0	8	42
<i>Eucryphia lucida</i>	0	0	0	0	0	17
<i>Olearia persoonioides</i>	0	0	0	0	0	17
<i>Anodopetalum biglandulosum</i>	0	0	0	0	0	25

* Only species with frequencies greater than 15% in at least one group are included.

† Groups as in the appendix.

sassafras–musk rainforest. The major differences between the Tasmanian and Victorian sassafras rainforests are that in Victoria the acacias (*Acacia dealbata*, *A. frigescens* and *A. melanoxylon*) are more common and *Elaeocarpus holopetalus* (blueberry ash, a small tree which is known from King and Flinders Islands but does not extend to mainland Tasmania) is common.

Outliers of warm temperate rainforest (dominated by *Acmena smithii*) reach to Wilsons Promontory but do not extend to Tasmania.

The phytosociology of Tasmanian cool temperate rainforest *per se* is discussed by Jarman *et al.* (1991). The floristic classification presented here agrees closely with that of Jarman *et al.*, although some difference is inevitable, given that Jarman *et al.* were considering rainforest throughout Tasmania, and that the present study only considered relict rainforest.

The floristics and structure of these rainforest communities are strongly influenced by the dominant tree species. *Nothofagus cunninghamii* and *Atherosperma moschatum* are the dominant rainforest trees throughout eastern Tasmania. The two species are markedly different in their habit, their ecological role, their epiphytic flora and their dispersal abilities. *Atherosperma moschatum* has plumose achenes which can be carried large distances, whereas *Nothofagus cunninghamii* seed, although winged, is rarely carried further than 40 m. It seems, therefore, a reasonable hypothesis, that *Nothofagus cunninghamii* has been eliminated from many areas which it has been unable to recolonise, whereas *Atherosperma moschatum* may also have been eliminated in the past but, via its superior seed dispersal ability, has been able to recolonise suitable sites. Those rainforest patches dominated by *Nothofagus cunninghamii* may therefore be viewed as true relicts, patches which have persisted since times of different climates, whereas patches dominated by *Atherosperma moschatum* may be true relicts, but, also, may have re-established following exogenous disturbance.

In eastern Tasmania, it appears that climate is directly limiting the distribution of rainforest. We have insufficient evidence to determine whether the floristic composition of rainforest in eastern Tasmania is controlled directly by climate or indirectly through the influence of climate on edaphic factors and/or fire.

Rainforest Conservation

All of the communities described above are well represented in state reserves and national parks. All except thamnic sassafras–laurel rainforest are also represented in forest reserves. A number of relict rainforest patches around the state are also within RAP (Recommended Areas for Protection) (Working Group for Forest Conservation 1990), which will probably result in further formal reservation of rainforest patches in the future. As rainforest within Nature Conservation Regions 4 and 7 is a rare plant community it is additionally protected from any forest-harvesting operations under the Forest Practices Act. Studies on the impacts of disturbance will be reported elsewhere.

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(accepted 9 December 1992)

APPENDIX

Floristics of the communities

1A. Callidendrous sassafras–musk rainforest (northeast)

Dominant species:

Atherosperma moschatum

Most prominent understorey species:

Olearia argophylla, *Dicksonia antarctica*, *Blechnum watsii*

Other species often present (trees and shrubs):

Acacia melanoxylon, *Pittosporum bicolor*, *Coprosma quadrifida*, *Parsonsia brownii*, *Pimelea drupacea* (herbs); *Grammitis billardieri*, *Histiopteris incisa*, *Hymenophyllum australe*, *H. cupressiforme*, *H. flabellatum*, *H. rarum*, *Hypolepis rugosula*, *Microsorium diversifolium*, *Polyphlebium venosum*, *Polystichum proliferum*, *Rumohra adiantiformis*, *Tmesipteris billardieri*, *Urtica incisa*

Additional species sometimes present (trees and shrubs):

Notelaea ligustrina, *Pomaderris apetala*, *Aristotelia peduncularis*, *Clematis aristata*, *Tasmannia lanceolata*, *Zieria arborescens* (herbs); *Asplenium bulbiferum*, *A. terrestre*, *Blechnum nudum*, *Ctenopteris heterophylla*, *Allantodia australis*, *Lastreopsis acuminata*, *Gahnia grandis*, *Hydrocotyle hirta*

1B. Callidendrous sassafras–musk rainforest (eastern highlands)

Dominant species:

Atherosperma moschatum

Most prominent understorey species:

Olearia argophylla, *Dicksonia antarctica*, *Polystichum proliferum*, *Microsorium diversifolium*

Other species often present (trees and shrubs):

Pittosporum bicolor, *Beyeria viscosa*, *Clematis aristata*, *Coprosma quadrifida*, *Pimelea drupacea* (herbs); *Asplenium terrestre*, *Blechnum watsii*, *Ctenopteris heterophylla*, *Grammitis billardieri*, *Histiopteris incisa*, *Hymenophyllum australe*, *H. cupressiforme*, *H. flabellatum*, *H. rarum*, *Hypolepis rugosula*, *Polyphlebium venosum*, *Rumohra adiantiformis*, *Tmesipteris billardieri*, *Hydrocotyle hirta*

Additional species sometimes present (trees and shrubs):

Acacia dealbata, *Notelaea ligustrina*, *Pomaderris apetala*, *Aristotelia peduncularis*, *Parsonsia brownii*, *Zieria arborescens* (herbs); *Asplenium bulbiferum*, *Blechnum chambersii*, *B. fluviatile*, *B. nudum*, *B. patersonii*, *Uncinia tenella*, *Urtica incisa*

2A. Callidendrous myrtle rainforest (highland)

Dominant species:

Nothofagus cunninghamii

Subdominant:

Atherosperma moschatum

Most prominent understorey species:

Olearia argophylla, *Dicksonia antarctica*, *Blechnum watsii*, *Polystichum proliferum*

Other species often present (trees and shrubs):

Acacia dealbata, *Pittosporum bicolor*, *Bedfordia salicina*, *Pimelea drupacea* (herbs); *Asplenium terrestre*, *Grammitis billardieri*, *Histiopteris incisa*, *Hymenophyllum cupressiforme*, *H. flabellatum*, *H. peltatum*, *H. rarum*, *Microsorium diversifolium*, *Tmesipteris billardieri*

Additional species sometimes present (trees and shrubs):

Acacia melanoxylon, *Leptospermum lanigerum*, *Notelaea ligustrina*, *Pomaderris apetala*, *Aristotelia peduncularis*, *Clematis aristata*, *Coprosma quadrifida*, *Tasmannia lanceolata* (herbs); *Rumohra adiantiformis*, *Drymophila cyanocarpa*, *Gahnia grandis*

2B. Callidendrous myrtle rainforest (riverine)

Dominant species:

Nothofagus cunninghamii

Subdominant:

Atherosperma moschatum

Most prominent understorey species:

Dicksonia antarctica, *Blechnum watsii*, *Polystichum proliferum*, *Microsorium diversifolium*

Other species often present (trees and shrubs):

Acacia dealbata, *A. melanoxylon*, *Notelaea ligustrina*, *Olearia argophylla*, *Pittosporum bicolor*, *Pomaderris apetala*, *Coprosma quadrifida*, *Monotoca glauca* (herbs); *Blechnum nudum*, *Grammitis billardieri*, *Histiopteris incisa*, *Hymenophyllum cupressiforme*, *H. flabellatum*, *Polyphlebium venosum*, *Rumohra adiantiformis*, *Sticherus tener*, *Tmesipteris billardieri*

Additional species sometimes present (trees and shrubs):

Aristotelia peduncularis, *Pimelea drupacea*, *Zieria arborescens* (herbs); *Asplenium terrestre*, *Hypolepis rugosula*, *Hymenophyllum australe*, *H. rarum*, *Todea barbara*, *Drymophila cyanocarpa*, *Gahnia grandis*, *Hydrocotyle hirta*, *Urtica incisa*

3. Thamnic sassafras-laurel rainforest

Dominant species:

Atherosperma moschatum

Most prominent understorey species:

Anopterus glandulosus, *Olearia argophylla*, *Dicksonia antarctica*,
Polystichum proliferum

Other species often present (trees and shrubs):

Pittosporum bicolor, *Pomaderris apetala*, *Clematis aristata*,
Coprosma quadrifida, *Cyathodes glauca*, *Pimelea drupacea*,
Tasmannia lanceolata (herbs); *Blechnum watsii*, *Ctenopteris*
heterophylla, *Grammitis billardieri*, *Histiopteris incisa*,
Hymenophyllum australe, *H. cupressiforme*, *H. flabellatum*, *H.*
rarum, *Microsorium diversifolium*, *Rumohra adiantiformis*,
Tmesipteris billardieri, *Hydrocotyle hirta*

Additional species sometimes present (trees and shrubs):

Notelaea ligustrina, *Phyllocladus aspleniifolius*, *Aristotelia*
peduncularis, (herbs); *Asplenium terrestre*, *Hypolepis rugosula*,
Polyphlebium venosum, *Gahnia grandis*

4. Callidendrous-thamnic myrtle rainforest (one community)

Dominant species:

Nothofagus cunninghamii

Subdominant:

Atherosperma moschatum

Most prominent understorey species:

Anopterus glandulosus, *Dicksonia antarctica*, *Blechnum watsii*

Other species often present (trees and shrubs):

Pittosporum bicolor, *Aristotelia peduncularis*, *Cenarrhenes nitida*,
Coprosma quadrifida, *Cyathodes glauca*, *Olearia argophylla*,
Tasmannia lanceolata (herbs); *Grammitis billardieri*, *Histiopteris*
incisa, *Hymenophyllum australe*, *H. peltatum*, *H. rarum*,
Microsorium diversifolium, *Polystichum proliferum*, *Rumohra*
adiantiformis

Additional species sometimes present (trees and shrubs):

Acacia melanoxylon, *Eucryphia lucida*, *Notelaea ligustrina*,
Phyllocladus aspleniifolius, *Pomaderris apetala*, *Anodopetalum*
biglandulosum, *Clematis aristata*, *Gaultheria hispida*, *Parsonsia*
brownii, *Pimelea drupacea*, *Richea dracophylla* (herbs); *Ctenopteris*
heterophylla, *Hymenophyllum flabellatum*, *Hypolepis rugosula*,
Sticherus tener, *Tmesipteris billardieri*, *Gahnia grandis*, *Uncinia*
tenella

SMALL TERRESTRIAL MAMMALS AND BATS OF MELALEUCA AND CLAYTONS, SOUTHWESTERN TASMANIA

by Robert J. Taylor and Michael D. Comfort

(with one table and one text-figure)

TAYLOR, R.J. & COMFORT, M.D., 1993 (31:viii): Small terrestrial mammals and bats of Melaleuca and Claytons, southwestern Tasmania. *Pap. Proc. R. Soc. Tasm.* 127: 33–37. ISSN 0080–4703. Forest Practices Unit, Forestry Commission, 30 Patrick Street, Hobart, Tasmania 7000 (RT); Parks and Wildlife Section, Department of Environment and Land Management, GPO Box 44A, Hobart, Tasmania 7001 (MC).

A survey of small terrestrial mammals and bats was undertaken in two areas of southwestern Tasmania: around Melaleuca, in sedgeland, scrub and woodland communities, and at Claytons in mixed forest. The density of bats was extremely low in comparison with populations in eastern Tasmania. The densities of *Rattus lutreolus* and *Antechinus minimus* were greatest in sedgeland/scrub with a dense undergrowth. *Pseudomys higginsi* was only captured in mixed forest but is also present around Deny King's garden. *Dasyurus viverrinus* was most abundant in young sedgeland. *Cercartetus nanus* was present at both Claytons and Melaleuca. No introduced rodents were trapped, but an outbreak of *Rattus rattus* had occurred previous to our study. No *Mastacomys fuscus* were trapped but they have been recorded in a previous study. Fire has an important influence on the composition and structure of the vegetation which, in turn, influences the composition and density of the mammal community.

Key Words: Small mammals, bats, sedgeland, rainforest, fire, southwestern Tasmania.

INTRODUCTION

The Department of Parks, Wildlife and Heritage (now Environment and Land Management) chose two areas in the Tasmanian Wilderness World Heritage Area (centred around Pelion Plains AMG 4208 3685 and Melaleuca 4322 1920 [in southwestern Tasmania]) to be used as baseline study sites. Extensive biological surveys are to be undertaken in these areas, so that any long-term changes can be monitored. This paper reports the results of a survey of small terrestrial mammals and bats around Melaleuca and in mixed forest at Claytons, northwest of Melaleuca, on the shores of Bathurst Harbour.

METHODS AND STUDY AREAS

Surveys were undertaken around Melaleuca between 25 February and 4 March 1991, and at Claytons between 1 and 3 March 1991. At Melaleuca, work was undertaken in different aged stands of sedgeland, around the walkers huts and in the garden of Deny King, who was a long-term resident of the area. At Claytons, trapping occurred in mixed forest and around the house.

The following vegetation/habitat types were recognised: **MIXED FOREST** — Forest with a canopy of *Eucalyptus nitida* and rainforest species (*Nothofagus cunninghamii*, *Andopetalum biglandulosum*, *Eucriphia lucida*, *Phyllocladus aspleniifolius*). The undergrowth was usually open but with some patches of *A. biglandulosum*, *Cenarrhenes nitida* and *Anopterus glandulosus*. Ground cover consisted mostly of mosses and *Blechnum wattsi*, with some *Gahnia grandis* and *Gleichenia dicarpa*.

SCLEROPHYLL WOODLAND WITH TALL SCRUB — Open *Eucalyptus nitida* woodland with tall dense tea-tree scrub (*Melaleuca squarrosa* and *Leptospermum scoparium*). Undergrowth was sparse with dense leaf litter and a few small scattered *Gahnia grandis*.

TALL SCRUB — Tea tree scrub greater than 3 m tall, some-

times with scattered eucalypts overtopping. The undergrowth showed some effects of shading by tea-tree but not to the extent of nearly complete elimination, as in the previous community. Dense patches of undergrowth were scattered through this community. Species dominant in the undergrowth included *Gahnia grandis*, *Gleichenia dicarpa*, *Restio tetraphyllus*, *Bauera rubioides*, *Calorophus elongatus*, *Gymnoschoenus sphaerocephalus*, *Tasmannia lanceolata*, *Lepidosperma elatius* and *Boronia citriodora*.

TALL SEDGELAND — Tea-tree shrubs 1.5–3 m tall, with *Gymnoschoenus sphaerocephalus* usually more prominent in the undergrowth compared with the previous community. Effects of shading of the undergrowth were not prominent. Common understorey plants included *G. sphaerocephalus*, *Gahnia grandis*, *Restio tetraphyllus*, *Gleichenia dicarpa* and *Calorophus elongatus*.

SEDGELAND — Height of vegetation was 0.5–1.5 m. Tea-tree and *Gymnoschoenus sphaerocephalus* dominant.

LOW SEDGELAND — Height of vegetation less than 0.3 m. Open ground was present between plants. Included recently burnt areas of sedgeland with dead 2 m tall stems of tea-tree. **HUTS** — This included trap locations beside, under, or close to the ranger's hut or bushwalkers huts.

KING'S GARDEN — This included areas around Deny King's garden and sheds where introduced plants (e.g. *Fuchsia*) were present. Undergrowth of some areas was dominated by *Blechnum nudum*, *Dicksonia antarctica* or *Hypolepis rugosula*. A large vegetable garden was present with apple and pear trees. Areas trapped included a shed with much spilt birdseed and the ground underneath the bird feeder, near the bird observatory.

CLAYTONS — Traps were placed in the garden and a shed in the immediate vicinity of the house at Claytons.

The age of the sedgeland, scrub and woodland stands was assessed from ring counts from stem portions taken at ground level from *Melaleuca squarrosa*, *Leptospermum scoparium*, and *L. glaucescens* (Jarman *et al.* 1988).

Trapping of small terrestrial mammals was undertaken with Elliot and break-back traps. Elliots were baited with a

mixture of peanut butter, rolled oats and oil. Break-backs were set with walnuts. In all, 178 trap sites in lines were set out, with between 10 and 25 m between traps. Traps were set for three to six nights. A single Elliot trap was placed at every trap site except one site in low, open sedgeland and four sites around the house at Claytons, where only a break-back was set. Two Elliot traps were placed in the seed shed and at the bird feeder in Deny King's garden. Break-back traps were placed nearby selected trap locations for the last one or two nights that the trap lines were set out, in order to try to catch species such as *Mastacomys fuscus* and *Sminthopsis leucopus*, which could be trap shy. There were a total of 631 trap nights for Elliots and 78 trap nights for break-backs.

The survey of bats utilised harp traps, mist nets and ultrasonic detectors. Locations suitable for the use of harp traps and mist nets were rare. The harp trap was used in two locations: near a machinery shed south of the airstrip (night of 25/26 February) and on the path from the bird observatory to Deny King's garden sheds, just near the edge of the tall scrub–open buttongrass boundary (nights of 17/18 February, 1/2, 2/3, 3/4 March). A mist net was set in King's vegetable garden on two nights: 27 February, 1945 to 2100 EST and 2 March, 1940 to 2045 EST. An ultraviolet light was placed nearby, in an attempt to attract insects and thence bats. Ultrasonic detectors were used to pick up the echolocation calls of bats. A detector was placed at four locations: on top of the water tank at the house at Claytons on the night of 1 March, next to ponds in buttongrass south of the airstrip on 25 February, on the bridge where the South Coast Track crosses Melaleuca Creek on 26 February and on the roof of Deny King's painting shed on 2 March. The output from these was taped for 45 min commencing at 2000 EST. A bat detector (Anabat II, Titley Electronics) was also usually carried during spotlighting. Five hours 15 min of spotlighting were undertaken, 70 min at Claytons and the rest around Melaleuca.

The Anabat computer program written by C. Corben (Queensland Forest Service) was used to produce a frequency–time display of a bat call, after passing the recording through a zero crossing analysis interface module

(Titley Electronics). The bat species was identified from the display of the call by comparing it with the calls of all species of Tasmanian bats recorded in eastern and north-western Tasmania (A. Duncan & R. Taylor, pers. obs.).

Weather conditions during the study were generally mild but cold rainy weather occurred on the night of 28 February and the following day.

RESULTS

Age of Vegetation Types

Ages of stands sampled from representative sites where trapping was undertaken were as follows: low, open sedgeland, 1–1.5 yrs (C. Arthur, pers. comm.); sedgeland, 14.2 ± 1.9 (5) ($x \pm SD$ [N]); tall sedgeland, 19.8 ± 2.3 (8); tall scrub 32.6 $\pm$ 5.2 (5); sclerophyll woodland, 35 ± 5.6 (3) and mixed forest, 250 yrs (Brown & Podger 1982).

Small Mammals

Trapping results for small terrestrial mammals are given in table 1. Density indices for each species in natural habitats are graphed in figure 1 as a function of time since firing. *Rattus lutreolus* densities were highest in sedgeland and scrub with a well-developed understorey. In areas with a sparse to very open undergrowth, no individuals were captured. Densities were lower in mixed forest than in scrub and sedgeland. Densities in King's garden were high. *Antechinus minimus* was trapped in older sedgeland, in scrub and in areas of King's garden with a well-developed undergrowth. *Pseudomys higginsi* was only trapped in mixed forest. However, two individuals were trapped by M. Driessen and M. Comfort in late May 1991 in tall sedgeland near the Ranger Hut, only 1–2 m from trap locations used in our study. *Dasyurus viverrinus* was more abundant in the younger ages of sedgeland and was not trapped in mixed forest. *Cercartetus nanus* was trapped on Deny King's kitchen bench and an individual was found in the bathtub at the house at Claytons. No terrestrial mammals were observed during spotlighting.

Bats

Output from the bat detectors was recorded for 3 h and detectors were monitored for a further 4 h 25 min whilst spotlighting. Two bat passes were detected. One of these was heard (but not recorded and was thus not identifiable) during spotlighting at the painting shed in King's garden. The other was recorded at the bridge over Melaleuca Creek. This latter call most closely resembled that of *Eptesicus regulus*. The rate of detection of bats was 0.24 passes per hour.

DISCUSSION

Trapping for bats at other sites in western Tasmania has found species diversity to be low (Taylor & O'Neill 1986). Taylor *et al.* (1987) thought that the cold conditions and high rainfall in western and southwestern Tasmania would limit populations in comparison with eastern Tasmania. The survey of bats at Melaleuca and Claytons revealed that there was a very low density of bats present. The number of bat

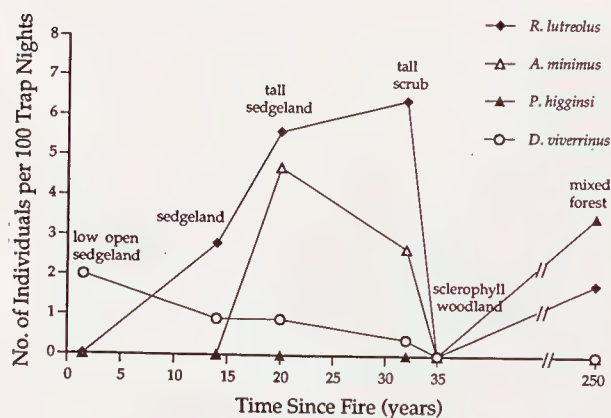


FIG. 1 — Density (number of different individuals/100 trap nights) of small terrestrial mammals in different vegetation types as a function of time since fire.

TABLE 1
Trapping results*

Habitat	Number of trap nights			Traps set off		<i>Rattus lutreolus</i>		<i>Antechinus minimus</i>		<i>Pseudomys higginsii</i>		<i>Dasyurus viverrinus</i>		Bird
	Elliott	Break-back	Total	Bait in	Bait taken	Total captures	Individuals/100 trap nights	Total captures	Individuals/100 trap nights	Total captures	Individuals/100 trap nights	Total captures	Individuals/100 trap nights	
Low sedgeland	39	10	49	7	14	0	0	0	0	0	0	1	2	2
Sedgeland	107	2	109	5	39	4	2.8	0	0	0	0	1	0.9	1
Tall sedgeland	91	16	107	0	5	17	5.6	8	4.7	0	0	1	0.9	1
Tall scrub	230	34	264	14	51	40	6.4	13	2.7	0	0	1	0.4	3
Sclerophyll woodland	34	2	36	2	1	0	0	0	0	0	0	0	0	0
Mixed forest	57	0	57	1	0	2	1.8	0	0	2	3.5	0	0	0
King's garden	58	6	64	2	2	7	4.7	2	3.1	0	0	0	0	0
Huts	15	0	15	0	3	0	0	0	0	0	0	0	0	0
Claytons	0	8	8	1	3	0	0	0	0	0	0	0	0	0

* For the mammals, both total captures and the number of different individuals are given.

passes recorded in dry forest in eastern Tasmania at a comparable time of year and time of night (R.J. Taylor & N.M. Savva, pers. obs.) was 80 times greater than that recorded during the present study. We recorded the presence of *E. regulus* during this study. M. Schultz and K. Menkhorst have previously recorded the presence of both *E. regulus* and *Nyctophilus geoffroyi* at Melaleuca (Taylor *et al.* 1987).

Both *Rattus lutreolus* and *Antechinus minimus* were most abundant in sedgeland/scrub areas with a dense ground cover. The sequence from low, open sedgeland through to mixed forest represents a time sequence of age since firing (Brown & Podger 1982, Jackson 1968). Populations of both species thus build up as the undergrowth recovers after fire but decline when ground cover dwindles due to shading from the canopy. *Rattus lutreolus* was present at lower densities in mixed forest than in sedgeland with dense ground cover. Ground cover is usually sparse in mixed forest but fallen logs, ferns and some shrub cover occur. Norton (1987) has shown that *R. lutreolus* densities are correlated with vegetation cover less than 0.5 m high and the amount of monocotyledonous food material present. Taylor *et al.* (1985) also found densities of *R. lutreolus* in rainforest (non-disturbed areas) were lower than in sedgeland with a dense undergrowth.

No *Antechinus* were trapped in the mixed forest. A further 73 trap nights in early February also failed to detect any *Antechinus* in this habitat (M. Comfort & M. Holdsworth, pers. obs.). *Antechinus swainsonii* is expected from this habitat. However, trapping intensity was probably lower than required to pick up the presence of this species. Taylor *et al.* (1985), for example, obtained no *A. swainsonii* in 549 trap nights in November and only one in 355 trap nights in January in rainforest in the Upper Henty River Region in western Tasmania. It would be interesting to undertake further trapping to see whether *A. swainsonii* or *A. minimus* were present in the mixed forest. Green (1979a) has found *A. minimus* in rainforest in northwestern Tasmania in the absence of *A. swainsonii*. The patches of mixed forest at Claytons are small (Brown & Podger 1982), and if populations of *A. swainsonii* were to die out here it would be difficult for the species to reinvade, as the area is isolated from other suitable habitat. In the absence of *A. swainsonii*, *A. minimus* may be able to utilise rainforest. Such competition between *Antechinus* species, influencing their habitat use, has been documented by Dickman (1986). *A. swainsonii* was caught by T. Pye (pers. comm.) in wet sclerophyll forest between Melaleuca and Cox Bight.

Pseudomys higginsii was trapped by us only in mixed forest. T. Pye (pers. comm.) also did not catch this species around Melaleuca but did trap it in wet sclerophyll forest between Melaleuca and Cox Bight. However, a specimen was obtained from Deny King which he had found near his house. He commented that he saw this species regularly but less frequently than *R. lutreolus*. Two individuals were trapped by M. Driessen and M. Comfort (pers. comm.) in tall sedgeland near the ranger's hut, two months after our study. It thus appears that a population exists in the vicinity of Deny King's house and nearby sedgeland. It seems that the species does not occur in other sedgeland areas sampled, or that numbers here are very low. Taylor *et al.* (1985), in the Upper Henty River region, and Hocking & Guiler (1983), in the Lower Gordon River region, found *P. higginsii* in sedgeland. (Hocking & Guiler [1983] actually refer to some of these communities as shrubland.) Densities are, however, three times greater in rainforest (Taylor *et al.* 1985). It may

be that sedgeland is a suboptimal habitat which is utilised only when other, more suitable habitats are present in an area. In this situation, individuals dispersing from other more suitable habitat can provide a "rescue effect" (Brown & Kodric-Brown 1977) for sedgeland populations. At Melaleuca, sedgeland dominates. The unnatural conditions in King's garden may bolster food for this species here compared with normal sedgeland situations, but population density is still low.

The preference of *Dasyurus viverrinus* for younger ages of sedgeland is in accord with findings for both wet sclerophyll (Hocking & Guiler 1983) and dry sclerophyll forest (Driessen *et al.* 1991), where numbers have been shown to increase after an area is burnt and then decline as the undergrowth recovers. It is probably easier for *D. viverrinus* to hunt in the more open undergrowth of young sedgeland and it is also possible that some invertebrate groups used as food would be more abundant in younger stages of sedgeland.

Cercartetus nanus is associated with areas of wet forest and has not been recorded from sedgeland (Green 1973). This species was thus expected from the wet forest at Claytons. However, it was also trapped in Deny King's kitchen. The unnatural conditions in the garden may allow it to persist around Melaleuca. Our trapping methods were not suitable to detect *C. lepidus* but it has previously been recorded by Deny King at Melaleuca (Queen Victoria Museum records). *C. lepidus* is undoubtedly present in sedgeland here as its presence in this habitat has been noted elsewhere (Green 1979b). A study of the relationship between sedgeland age and *C. lepidus* populations is warranted, in order to assess the implications of prescribed burning of sedgeland in the area.

Mastacomys fuscus is only present in older stands of sedgeland (Hocking & Guiler 1983). The species was trapped by T. Pye (pers. comm.) in sedgeland near the walking track between the airstrip and the ranger's hut. However, no evidence of its occurrence was found by us. It has been trapped in sedgeland areas alongside streams, near the Scotts Peak Road (Driessen & Comfort 1991) and in the Norfolk Range region in northwestern Tasmania (Slater 1992). These areas appear to be similar to some we trapped. Break-back traps were used by us in the hope of trapping this species if it avoided the Elliot traps. However, this tactic did not prove successful. The species has been caught elsewhere in both Elliot and break-backs with the same bait mixtures as we used. The sedgeland in the vicinity of the location where T. Pye trapped *M. fuscus* has been burnt since he conducted his trapping, and it is possible that suitable habitat for the species may have been destroyed.

Introduced rodents are generally thought to be absent from southwestern Tasmania and neither Hocking & Guiler (1983) nor Taylor *et al.* (1985) recorded them. We caught no live individuals. However, Deny King had a preserved specimen of *Rattus rattus* that he had trapped several months previous to our study. He reported the outbreak of the species at this time as being the first he had known. He thought the species might have been introduced in the cargo of a Caribou aircraft, as the outbreak occurred after the landing of one of these at Melaleuca.

Fire is the most important factor influencing the terrestrial mammal populations in the study area via its effect on the vegetation. Different species were found to favour different ages of sedgeland and to be dependent on vegetation types which required different fire-free periods. Fire regimes in sedgeland and the protection of the small pockets of fire-

sensitive vegetation are the most important factors which need to be considered by the Parks and Wildlife Section in determining management of the mammal populations around Melaleuca.

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THE LICHEN GENUS *CHIODECTON* IN TASMANIA

by G. Kantvilas and G. Thor

(with one text-figure and one plate)

KANTVILAS, G. & THOR, G., 1993 (31:viii): The lichen genus *Chiodecton* in Tasmania. *Pap. Proc. R. Soc. Tasm.* 127:39–41. ISSN 0080-4703. Tasmanian Herbarium, GPO Box 252C, Hobart, Tasmania 7001 (GK); Department of Botany, Stockholm University, S-106 91 Stockholm, Sweden (GT).

Three species of *Chiodecton* occur in Tasmania: *C. colensoi*, the endemic *C. flavovirens*, and *C. montanum* which is reported here from Australia for the first time. It was known previously from two localities in New Zealand. A key to these three Tasmanian species is provided, together with notes on their ecology and distribution.

Key Words: lichens, Tasmania, *Chiodecton*.

INTRODUCTION

Chiodecton is a crustose genus in the lichen family Opegraphaceae, characterised by ascocarps aggregated into thalline, stroma-like structures, anticlinally arranged, sparsely branched excipulum hyphae, sparsely branched paraphysoids, and by thin-walled, fusiform, usually three-septate ascospores. The thallus typically has an orange-pink tinge when fresh (due to the presence of the alga *Trentepohlia*) and the thalline stromata are convex, rounded or irregularly elongate, and mostly to 2 mm wide. The minute apothecial discs, c. 0.1 mm diam., are visible as numerous black dots or short lines on the surface of the stroma. The epithecium and hypothecium are typically dark brown, turning dull olive-grey in KOH. Most species are superficially similar in gross morphology (pl. 1) and differ chiefly by anatomical characters.

The genus is primarily tropical-subtropical in distribution, although *C. colensoi* extends into temperate areas and *C. montanum* and *C. flavovirens* are confined there. Most species of *Chiodecton* are corticolous in moist, sheltered habitats and only *C. montanum* is strictly saxicolous. However, four other species, *C. colensoi*, *C. congestulum*, *C. leptosporum* and *C. malmei*, occasionally occur on rocks (Thor 1990).

Kantvilas (1989) recorded only one species of *Chiodecton* from Tasmania, *C. colensoi* (Massal.) Müll. Arg., a widely distributed lichen in eastern Australia and New Zealand. In a revision of the genus, Thor (1990) described a further species, *C. flavovirens* Thor which is apparently endemic to Tasmania. Recently one of the authors (GK) collected a third species from Tasmania, *C. montanum* Thor, previously known only from New Zealand.

KEY TO CHIODECTON IN TASMANIA

1. Hymenium interspersed with oil droplets and granules.. 2
Hymenium lacking oil droplets or granules.. *C. colensoi*
2. Thallus saxicolous; lower part of the medulla with yellow pigments, mainly in the stroma-like ascocarps
..... *C. montanum*
Thallus corticolous, lignicolous or occurring on dead leaves; lower part of the medulla lacking yellow pigments
..... *C. flavovirens*



PLATE 1

Chiodecton colensoi, showing typical wart-like thalline stromata with minute blackish apothecial discs, visible as black dots and lines on the surface of each stroma (photo Bruce Fuhrer).

THE SPECIES

1. *Chiodecton colensoi* (Massal.) Müll. Arg.,
Bull. Herb. Boissier 2: App. 1: 86 (1894)

A full description and discussion of the morphology, anatomy and distribution of this species are given by Galloway (1985) and Thor (1990). For photograph see plate 1. It is characterised chiefly by the absence of abundant oil droplets in the hymenium. *Chiodecton colensoi* is the most common Tasmanian species of the genus (fig. 1), being widespread in a wide range of cool temperate rainforest vegetation as well as occurring in some wet sclerophyll forests. It occurs exclusively on smooth bark, usually in shaded, moist microhabitats, and typical host trees include *Atherosperma*, *Anodopetalum*, young *Nothofagus cunninghamii* and *Tasmania*. In rainforest, common lichens associated with *Chiodecton colensoi* include *Phaeographis exaltata*, *Megalospora lopadioides*, *Parmeliella nigrocincta*, *Phlyctis subuncinata*, *Thelotrema lepadinum*, *Opegrapha stellata* and *Coccotrema cucurbitula*. The record from Tasmania of *Chiodecton perplexum* Nyl. by Shirley (1894) refers to *C. colensoi* (Kantvilas 1988).

Selected specimens examined: Australia, Tasmania: Mount Arthur, 1885–95, F.R.M. Wilson 1115 (G, COLO). Weldborough, 41°12'S, 147°54'E, on *Atherosperma moschatum* in rainforest, 770 m a.s.l., 1981, Kantvilas 1135/81 (HO, BM). Arthur River, on *Nothofagus cunninghamii* in rainforest, 270 m a.s.l., 1982, Kantvilas 65/82 (HO, BM). Mt Dundas track, 41°55'S, 145°28'E, on *Anodopetalum biglandulosum* in rainforest, 670 m a.s.l., 1988, Kantvilas 541/88 (HO). Balts Spur, Tasman

Peninsula, 43°05'S, 147°56'E, on canopy twigs of *Nothofagus cunninghamii*, 420 m a.s.l., 1983, Kantvilas 157/83 (HO). Murchison Highway at saddle over Mt Black, 41°47'S, 145°35'E, on *Anodopetalum biglandulosum* in rainforest, 530 m a.s.l., 1989, Kantvilas 269/89 (HO). Track to The Blade, Cape Pillar, 43°14'S, 148°00'E, 1973, M. Kershaw s.n. (HO). Anthony Road near Lake Sandra Track, 41°50'S, 145°36'E, on *Anodopetalum biglandulosum* in rainforest, 580 m a.s.l., 1989, Kantvilas 31/89 (HO). Little Fisher River, 41°45'S, 146°20'E, on *Atherosperma moschatum* in rainforest, 820 m a.s.l., 1984, Kantvilas 705/84 (HO, BM). Mount Wellington, alt. 600 m [2000 feet], 1891, W.A. Weymouth 118 (VT). St Marys Pass, 1891, F.R.M. Wilson s.n. (G).

2. *Chiodecton flavovirens* Thor,
Opera Botanica 103: 41 (1990)

See Thor (1990) for a full description and photograph. *Chiodecton flavovirens* is an uncommon Tasmanian endemic lichen from wet forests. Superficially similar to *C. colensoi*, it is characterised by the presence of oil droplets and granules in the hymenium, and by its unique ecology. It is known from highland areas where it grows in locally dry microhabitats such as on the papery, fibrous bark of *Leptospermum lanigerum* and on the dead leaves of *Richea pandanifolia* (Thor 1990). The latter habitat tends to be particularly rich in lichens with typical species including *Lecanactis abietina*, and species of *Chaenotheca*, *Cliostomum* and *Opegrapha*.

Additional specimen examined (see also Thor 1990): Australia: Tasmania: Track to Nevada Peak, 42°54'S, 146°41'E, on dead dry leaves of *Richea pandanifolia* in rainforest, 800 m a.s.l., 1993, Kantvilas 19/93 (HO, S).

3. *Chiodecton montanum* Thor.,
Opera Botanica 103: 52 (1990)

A full morphological description and photograph are provided by Thor (1990). *Chiodecton montanum* is characterised by the presence of yellow pigments (secalonic acid derivatives and skyrin) in the medulla, a thallus closely attached to the substrate, and an hymenium interspersed with oil droplets and granules. The species is most closely related to *C. flavovirens* (see key above) from which it is distinguished by the additional characters of a darker thallus colour and the presence of a prothallus (sometimes almost lacking).

In collections of *C. montanum* from Tasmania, only small amounts of the yellow pigments are present in the medulla surrounding the ascocarp. Hence these are detected best in microscope preparations where the pigments turn red and dissolve in KOH. Tasmanian material also differs from New Zealand material by the slightly shorter ascospores: material from Tasmania — (41–) 43–50 (–56) × (3–) 3–4 (–4) µm (length: X = 46.5 µm, SD = 3.1 µm, n = 120; width: X = 3.2 µm, SD = 0.4 µm, n = 120); material from New Zealand — (44–) 47–53 (–57) × (3–) 3 (–4) µm (length: X = 50.0 µm, SD = 3.0 µm, n = 60; width: X = 3.1 µm, SD = 0.2 µm, n = 60). Material of *C. colensoi* from Australia has similarly slightly shorter spores than the material from New Zealand (Thor 1990).

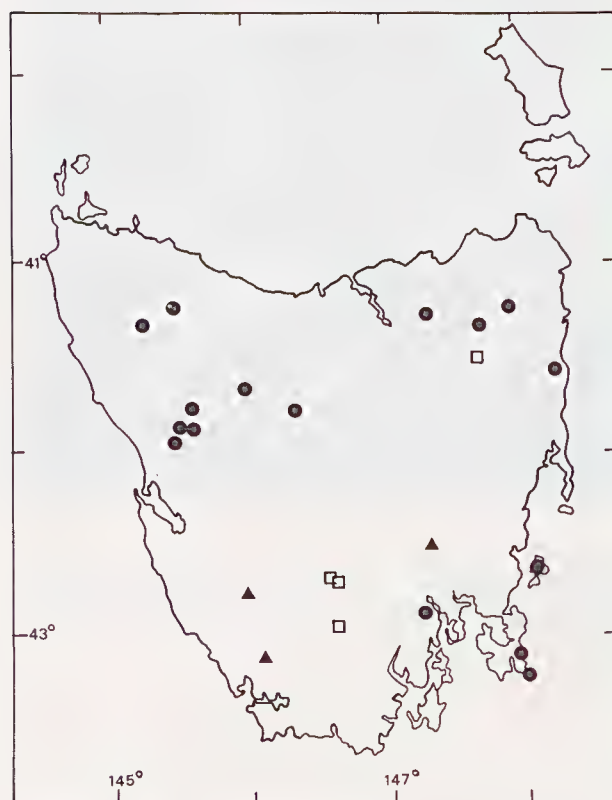


FIG. 1 — Distribution of *Chiodecton* in Tasmania: *C. colensoi* (●); *C. flavovirens* (□); *C. montanum* (▲)

Distribution and habitat

Chiodecton montanum was known previously from only two localities in New Zealand, one in the North Island (1000 m a.s.l.) and one in the South Island (1080 m a.s.l.) (Thor 1990). In Tasmania, *C. montanum* is known from three localities (fig. 1). Two are from Precambrian metamorphic peaks in the remote southwestern area, where the species was associated with normally corticolous species such as *Megalospora lopadioides* and species of *Sphaerophorus*. This region is characterised by a high rainfall (up to c. 3000 mm per annum) and supports a highly interesting lichen flora, rich in endemic species or taxa with a restricted distribution, especially from genera of Gondwanan origin, e.g. *Siphula* (Kantvilas *et al.* 1992, Kantvilas & Jarman 1991). The third locality is from dolerite rocks in southeastern Tasmania, where *C. montanum* was associated with *Rinodina murrayi* and species of the Parmeliaceae. This is a most remarkable ecological disjunction, in that this locality is in a markedly drier (annual rainfall c. 700 mm), milder macroclimate and, with the apparent notable exception of *Chiodecton montanum*, shares very few cryptogam or phanerogam species with the southwestern mountains. At all three localities, *Chiodecton montanum* occurs in moist, very sheltered rock crevices.

Chiodecton montanum is a further example of a southern Australian/Tasmanian–New Zealand disjunction. Biogeographic connections between these regions are well known and have been discussed by many authors (e.g. Galloway 1990). Similar distributions have been found in, for example, species of *Megalospora* (Sipman 1983), *Sphaerophorus* (Tibell 1987) and, most recently, *Roccellina* (Tehler *et al.* 1991).

Specimens examined: Australia, Tasmania: Mt Sprent, on sheltered overhangs amongst alpine quartzite boulders, 42°48'S, 145°58'E, 1050 m a.s.l., 1984, Kantvilas 550/84 (BM, HO); Little Quoin, on vertical dolerite cliff face in eucalypt forest, 1988, Kantvilas 602/88 (HO); Green Head, c. 3 km SSE of Greystone Bluff, on vertical and overhanging Precambrian metamorphic rocks in alpine moorland, 43°06'S, 146°04'E, 800 m a.s.l., 1991, Kantvilas 75/91 (HO, S).

ACKNOWLEDGEMENTS

We thank Mr B. Fuhrer for use of his photograph and Dr G.N. Stevens for helpful comments on the manuscript.

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(accepted 6 May 1993)

THE ECOLOGY AND CONSERVATION MANAGEMENT OF THE PTUNARRA BROWN BUTTERFLY *Oreixenica ptunarra* (LEPIDOPTERA; NYMPHALIDAE; SATYRINAE) IN TASMANIA, AUSTRALIA

by Mark G. Neyland

(with one table and four text-figures)

NEYLAND, M.G., 1993 (31.viii): The ecology and conservation management of the ptunarra brown butterfly *Oreixenica ptunarra* (Lepidoptera; Nymphalidae; Satyrinae) in Tasmania, Australia. *Pap. Proc. R. Soc. Tasm.* 127: 43-48. ISSN 0080-4703. Parks and Wildlife Service, Department of Environment and Land Management, GPO Box 44A, Hobart, Tasmania 7001.

The ecology and conservation status of the rare Tasmanian endemic butterfly *Oreixenica ptunarra* Couchman was investigated over a three-year period. One hundred and fifty colonies of the butterfly have been located in areas of *Poa*-dominated native grassland across central Tasmania. Most colonies are small and all are under pressure from continuing stock grazing. Without active intervention the species will continue to decline. A recovery plan for the butterfly has been written, implementation of which will commence in March 1993.

Key Words: butterflies, *Oreixenica*, Tasmania, insects, conservation.

INTRODUCTION

The endemic ptunarra brown butterfly *Oreixenica ptunarra* (Couchman) is the most recently described new species from Tasmania (Couchman 1953). Three subspecies of the butterfly have been named; *O. p. ptunarra*, the smallest and darkest of these, occurs in the Central Region (biogeographic regions follow those of the Tasmanian Forestry Commission [Orchard 1988]); *O. p. roonina*, the largest and brightest subspecies, is found in the Centre and the Southern Midlands; *O. p. angeli*, which is intermediate in size and colour to the other two, occurs on the East Coast and Tiers (Couchman 1953).

By the 1980s it was recognised that the species was in decline and, following a study by Prince (1988), who found that it had suffered significant habitat loss and disturbance, the species was listed as endangered (following the IUCN Red Data Book definitions in Wells *et al.* 1983). This paper presents the results of a three-year study into the ecology and conservation needs of this butterfly. The aim of the study was to identify the habitat of the butterfly, the extent and condition of its remaining habitat, its distribution and the threats to its continuing survival.

METHODS

Distribution and Site Studies

Prince (1988), identified 33 locations for the butterfly from the records of other collectors, in particular, L. Couchman and G. Ellis. Following a study of these sites and the identification of a potential habitat profile, a register of potential sites was developed based on the known sites, air photo interpretation and field surveys. Additionally, around 150 potential sites from a recent survey of native grasslands in Tasmania (Kirkpatrick *et al.* 1988), fell within the range of the butterfly, giving a total of over 400 potential sites. The floristics, altitude, slope, aspect, geology, soil type, topographic position, bare ground (%), relative cover of native versus introduced vegetation, *Poasp.* cover (%), vegetation structure, fire history, grazing history and recent management history, including significant disturbance events, were recorded at

every site. An estimate of solar radiation based on the horizon angle was also recorded.

Population Surveys

As many sites as possible were visited during the short flight season, and the presence and relative abundance of the butterfly were recorded. Formal counts, after the method of Pollard (1977), were made whenever possible. These counts involved walking through a butterfly colony along a random route and counting all butterflies observed over a twenty-minute period. Counts were only conducted under good weather conditions (light winds and over 18°C). The earliest and latest dates that the butterfly was observed from each biogeographical region was recorded.

Larval Food Plant

Larvae were collected from a number of sites in order to identify the larval food plants and to attempt captive rearing.

Conservation Status

An assessment of the conservation status of each site was made on the basis of the size of the site, the health and abundance of tussock grass (*Poasp.*), the observed numbers of butterflies and the land tenure of the site. Sites were rated on a favourability scale of 1-3. Those sites which are in excellent condition, show no indication of disturbance by European occupation, are large in area and are rich in butterflies were rated "1". Sites rated "3" are those where the butterfly appears likely to become extinct in the near future. Sites rated "2" are intermediate.

Data Analysis

The floristic data were stored on a mainframe computer and manipulated using DECODA (Minchin 1990). The floristics were initially analysed using DECORANA (DCA) (Hill & Gauch 1980) and TWINSpan (Hill 1979). The ordination (DCA) scores were then analysed against the various site factors, using Pearsons product moment correlation analysis

to identify which factors, if any, were related to the DCA scores, and hence to determine which factors were important with respect to the distribution of the butterfly.

Climatic Profile

The computer program BIOCLIM (Busby 1986a, Nix 1986) was used to explore the extent to which the distribution of the butterfly is related to climatic factors. BIOCLIM calculates a climatic profile for a species based on 16 different climatic parameters, such as the mean temperature of the coolest month, the mean temperature of the warmest quarter and so on. The climate profile was calculated separately for each of the three subspecies. Subspecies *O. p. roonina* was further subdivided into the Midlands colonies and those from the Northwest Plains, as it was considered likely that the two areas would have differing climatic profiles. The profile of the species as a whole was also examined. BIOCLIM also calculates a predicted distribution for the species, based on the correlation between the known distribution and the climatic profiles of points outside the known range of the species. Points which fail to match all 16 parameters within the total climatic range of the species are not plotted. Points which match all 16 parameters within the total range are plotted as “-”; points which match all 16 parameters within the 90 percentile range (5–95%) as “+”; points which match 13–15 of the parameters within the interquartile range (25–75%) as “Ø”; points matching all 16 parameters within the interquartile range as “\$” (Busby 1986b). In other words, the program indicates where there are areas with climates which closely match the climate of the known range of the species. Experience suggests that the points labelled “+”, “Ø”, or “\$” are the most likely predictors of suitable areas.

RESULTS

Distribution

The range of the butterfly extends over three biogeographical regions within the State, the Centre, the Southern Midlands and the East Coast and Tiers (Orchard 1988). The Centre is divided here into three subregions, the northwestern portion (that part of the Centre region north and west of Cradle Mountain), being referred to hereafter as the Northwest Plains, the central portion being referred to as the Central Plateau and the southeast portion (that part of the Centre region south and east of the Steppes Historic Site), being referred to as the Steppes. *O. p. ptunarra* occurs only on the Central Plateau. *O. p. roonina* occurs on the Northwest Plains, the Steppes and the Southern Midlands, and *O. p. angeli* occurs on the East Coast and Tiers.

The Central Plateau region ranges from 900–1400 m a.s.l. The topography is undulating and rugged, with thousands of lakes dotting the dolerite surface. Patchy grasslands and grassy shrublands extend across the entire plateau, but whether the current vegetation resembles the pre-European vegetation or whether the recent history of the plateau has caused significant changes to the vegetation remains the subject of much speculation (Jackson 1973). *Oreixenica p. ptunarra* was thought to occur in suitable habitat throughout the region, but the evidence from the 1992 field season suggests that the butterfly may be quite restricted in its distribution. It is now thought likely that

the butterfly is restricted to the environs of Great Lake and Arthurs Lake and does not extend to the western Central Plateau.

The Northwest Plains is a recently discovered extension to the known range of *O. ptunarra*. The region extends north and west from the Great Western Tiers as broad ridges and plains, ranging from 500–900 m a.s.l. The soils are generally fertile but a combination of frosts and fire has perpetuated a mosaic of grasslands, eucalypt forests and rainforests. The vegetation pattern in the northeastern highlands is very similar and the ecological relationships there have been described in detail by Ellis (1985). In particular, regular firing by Aborigines is believed to have maintained the open grassy nature of the vegetation. The butterfly is generally found in grassy open woodland, dominated by either *Eucalyptus rodwayi* and/or *E. delegatensis* or in open grasslands dominated by *Poa labillardieri*.

The Steppes is a region of gently undulating, sometimes poorly drained country, ranging from 500–900 m a.s.l. The slopes generally support *E. delegatensis* dominated wet forest. Locally poorly drained areas support grassy *E. rodwayi* woodland, which still supports some large populations of the species. Grassy plains are locally extensive and, where they are not significantly altered by grazing or firing, they still support colonies of the butterfly. Recent developments in high-altitude grass species have resulted in an increase in the rate of land clearing in the area. Woodchipping operations have also had an impact on the butterfly. *O. p. roonina* is widespread through the region.

The Southern Midlands region is a lower surface of hills, gullies and plains, ranging from 250–600 m a.s.l. Originally the vegetation of the Midlands was a mosaic of grasslands, woodlands and open forests (Fensham 1989). Approximately 90% of the Midlands has since been converted to improved pasture (Fensham 1989). This ongoing process has had a dramatic effect on the butterfly. Throughout the Midlands, populations of the butterfly (*O. p. roonina*) are found only in lowland *Poa labillardieri* tussock grasslands.

The East Coast and Tiers extend up the central east coast of Tasmania, reaching a high point of 971 m at Snow Hill, but generally ranging from 0–800 m a.s.l. The area comprises moderately dissected dolerite hills carrying dry or wet sclerophyll forests invariably dominated by *Eucalyptus* species. Poorly drained areas, notably around Lakes Tooms and Leake and around the headwaters of the Macquarie River, carry grassy and/or sedge open woodland communities, often dominated by *E. rodwayi*, in which *O. p. angeli* is occasionally found.

Population Surveys

One hundred and fifty colonies of the butterfly have been located to date, after three years of intensive searching. The Southern Midlands, the East Coast and Tiers and the Northwest Plains have been systematically searched, but it is likely that additional colonies will be discovered in the future on the Central Plateau and on the Steppes. Four colonies extant in 1988 are believed to have now become extinct. The most significant of these was that at Mike Howes Marsh, the type locality for *O. p. roonina*.

Most extant colonies are smaller than 10 ha and only 20 colonies exceed 50 ha (fig. 1). The net area of *O. ptunarra* habitat is very roughly estimated at 4000 ha. Figure 2 shows the different conservation status of the various colonies.

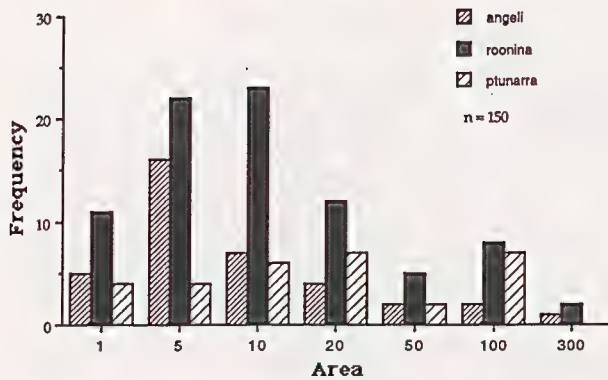


FIG. 1 — The areas of all known sites by size (ha).

Life History

The butterfly flies in autumn for about two weeks at any given site. Butterflies are usually seen in numbers only, on days of mild weather with light breezes (temperatures above 18°C and winds below 15 knots). Males emerge earlier than females, and upon emergence the females are soon mated. Egg-laying follows shortly after mating. The eggs are non-sticky and are simply dropped into *Poa* tussocks, often while butterflies are on the wing. The eggs hatch in about six weeks and the larvae feed through the winter and into the following summer, pupating in February for four to five weeks, the imago emerging in mid to late March (Couchman 1953).

Food Plant

The larvae feed at night on the tips of *Poa* species (snow grasses). Four species have been identified as food plants. Larvae were collected from three species of *Poa*, the fourth is the only species of *Poa* at the site (*P. clelandii*) (nomenclature follows Buchanan *et al.* 1989) and is therefore likely to be the host plant. The four species are *Poa labillardieri* (var. *labillardieri* and var. *acris*), *P. rodwayi*, *P. gunnii* and *P. clelandii*. *Poa sieberiana* and *P. hookeri* were also present on some sites and may also be food plants.

Flight Dates

The times of first emergence for the different subspecies of the butterfly in each of the five biogeographical regions within its range are given in table 1. The butterfly emerges earlier in the higher altitude regions, those on the Central Plateau emerging up to two weeks earlier than those on the Southern Midlands.

Data Analysis

The DECORANA analysis shows that the butterfly occupies a characteristic ecological niche (fig. 3). Sites circled are those from which butterflies were not recorded, those to the left being predominantly grasslands dominated by kangaroo grass, *Themeda triandra*, in the dry eastern Midlands, those to the right being high altitude grassy sites.

Correlation analysis of the DCA scores against the site factors shows that the first axis of the DCA is highly significantly related to altitude ($r = 0.8713$, $P < 0.0001$, $n = 338$). The second axis of the DCA is significantly related to the cover of *Poa* ($r = 0.1959$, $P < 0.001$, $n = 338$), and to the percentage of bare ground on the site ($r = 0.2613$, $P < 0.0001$,

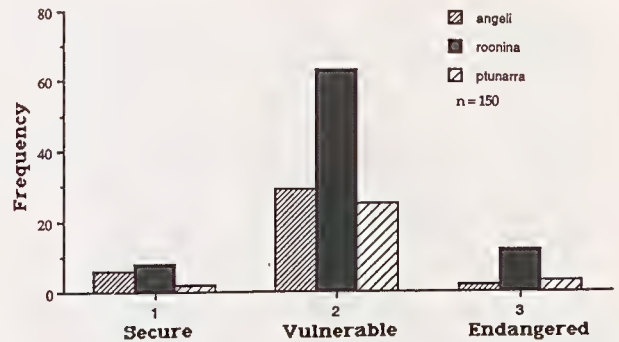


FIG. 2 — The conservation status of known colonies of each subspecies.

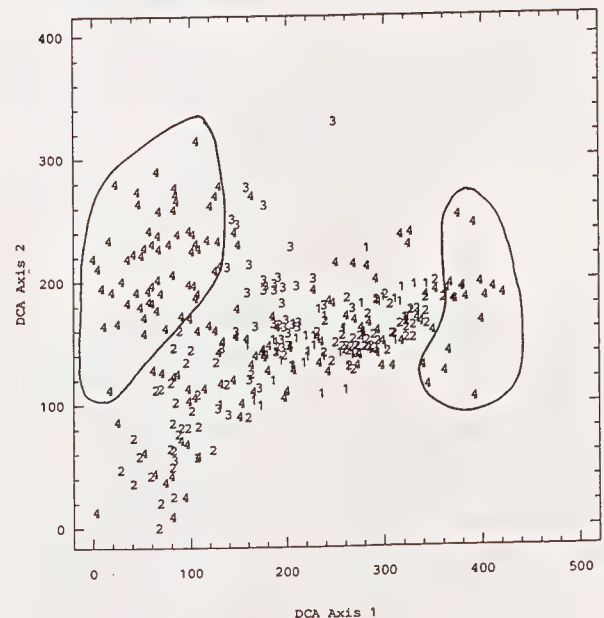


FIG. 3 — Scatterplot of all sites on the first two ordination axes. Sites labelled 1, 2 or 3 are those which carry butterflies. Sites labelled 4 do not carry butterflies.

$n = 338$), factors which are obviously related. The presence or absence of the butterfly is significantly correlated with the cover of *Poa* ($r = 0.1999$, $P < 0.0005$, $n = 338$).

Climatic Profile

The climatic profile, as indicated by the predicted distribution of each subspecies, is very narrow (fig. 4). With the exception of subspecies *roonina* in the Southern Midlands, it appears that the full potential range of each subspecies is occupied. *Oreixenica p. roonina* in the Southern Midlands is shown to have potential to expand to the southwest of its present range. This area no longer contains any suitable habitat, as a result of clearing and grazing pressures.

When the collective climate profile is examined, the predicted range matches the known range quite closely, with the notable exception of the northeast highlands (fig. 4). The analysis indicates that the climate in the northeast highlands is suitable, and suitable habitat is known to occur there, but searches by previous authors (Couchman 1977) in the area have failed to locate the butterfly.

TABLE 1
Flight dates for the different regions

	First recorded emergence	Last recorded emergence	Alt. range (m) (approx.)
Central Plateau	12.iii.1991 5.iii.1992		750–1200
Steppes	16.iii.1990 10.iii.1991 7.iii.1992	4.iv.1990	600–1000
Northwest Plains	10.iii.1992		500–900
East Coast and Tiers	18.iii.1990 16.iii.1991 17.iii.1992	30.iii.1990	400–800
Southern Midlands	16.iii.1990 23.iii.1991 17.iii.1992	3.iv.1990 7.iv.1991	300–750

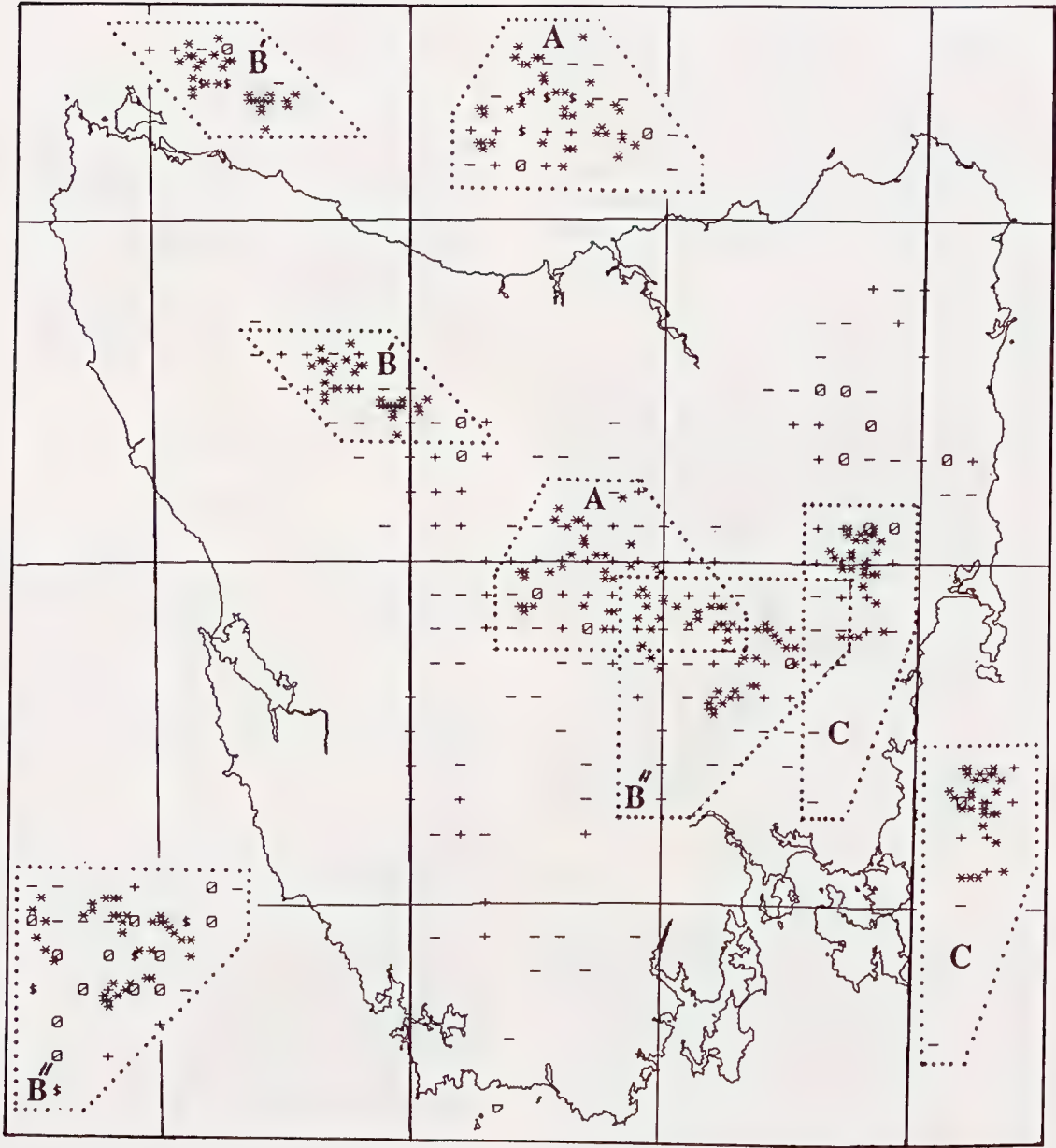


FIG. 4 — The actual and predicted (using BIOCLIM) range of *Oreixenica ptunarra*. The insets show the actual (asterisks) and predicted ranges of the three sub-species. Note that for *O. p. roonina* the predicted ranges for the Steppes and Southern Midlands and for the Northwest Plains were calculated separately A — *O. ptunarra ptunarra*; B' — *O. ptunarra roonina*, Northwest Plains; B'' — *O. ptunarra roonina*, Steppes and Southern Midlands; C — *O. ptunarra angeli*.

DISCUSSION

The ptunarra brown does not extend into the drier lowland grasslands in the Northern Midlands, or into the high-altitude grasslands of the western Central Plateau. However, there are potentially suitable sites within the broader range of the butterfly that do not carry butterflies. That there are no significant floristic differences between these sites and those with butterflies suggests that the absence of butterflies may be related to the site history or to other site factors. For example, the site may have been cleared at some time in the past and has since been recolonised by tussock grasses. Although the habitat now appears suitable for the butterfly, it is possible that, in the absence of suitable habitat corridors, the butterfly is unable to recolonise such sites from nearby colonies. Some vacant sites, especially in the Southern Midlands, appear suitable for possible re-introductions of the butterfly.

The bioclimatic analysis indicates that the butterfly now occupies its full potential range, with the possible exception of the northeast highlands. Within its range, the butterfly is limited mostly by the availability of habitat. In the Northwest Plains, suitable grasslands develop only on more fertile soils, and to the west and south of the Northwest Plains, grasslands are replaced by sedgeland as basalts are replaced by less fertile parent materials. The link between the Northwest Plains and the Central Plateau has yet to be determined. That the butterfly does not extend to the western Central Plateau is puzzling, although the results of the multivariate analysis indicate that the climate may be prohibitive. It is also possible that the butterfly has been eradicated from the Central Plateau by a European history of overfiring and overgrazing. In the late 19th century, there were over 350 000 sheep and 6000 cattle on the Central Plateau (Shepherd 1973). To the southwest of the Central Plateau and the Steppes regions, the butterfly is again, as in the Northwest, restricted by the availability of habitat, as vegetation changes in response to changing soils. In the Southern Midlands and the East Coast and Tiers, the butterfly was found wherever there was suitable habitat. In both regions suitable habitat is sparse.

The butterfly's key requirement is a healthy cover of *Poa* sp. tussock grass extending over at least one hectare. The strongest colonies observed were in areas of more than 50 ha. That the butterfly is now endangered is directly related to the attrition and fragmentation of available habitat caused by land clearing.

Conservation Status

All three subspecies of the butterfly are currently considered endangered (Neyland 1992). *Oreixenica p. roonina* is found in three distinct regions, the Southern Midlands, the Steppes and the Northwest Plains. In 1988, only eight populations were known from the Southern Midlands and all of these were considered endangered. Recent surveys in the Southern Midlands have located ten additional populations of the species but all are considered endangered. All suitable habitat in the region has now been surveyed, and it is considered that there is little potential for finding further colonies. Four populations have become extinct since a survey in 1988 (Prince 1988). All the existing colonies are small and grazed by sheep and/or cattle.

In the Steppes region, the butterfly is more widespread, but all colonies are subject to grazing. Grazing pressures are variable. Only one site is considered secure at present.

In the Northwest Plains region, the butterfly occupies a distinct ecological niche in grasslands and grassy woodlands. These grasslands are naturally restricted in their extent, and large areas have recently been converted to eucalypt plantation.

Oreixenica p. angeli is very restricted in its distribution, and is known only from grassy woodland and grassy open forest in the East Coast and Tiers. Despite a long history of overgrazing and overfiring in its habitat, *O. p. angeli* persists through most of its range, although numbers are low at many sites.

Prince (1988), on the basis of "a number of relatively secure populations and considerable areas of unexamined potential habitat", considered *O. p. ptunarra* to be secure on the Central Plateau. However, the absence of the butterfly from large areas of apparently suitable habitat suggests that the butterfly is not as widespread on the Central Plateau as previously considered. If, indeed, the butterfly is restricted to the eastern Central Plateau, then most of the Central Plateau colonies are located on private land and are sensitive to the same pressures as colonies in the Southern Midlands and elsewhere. Further fieldwork is required on the plateau before its range can be accurately defined.

Land Clearing

The species is absent from areas which have been converted to pasture (Prince 1988). Large areas which were originally native grassland and open grassy woodland in the Steppes and Southern Midlands have been cleared and converted to pasture, resulting in the loss of large areas of butterfly habitat. Many existing populations are found on the fringes of areas which would once have supported large colonies of butterflies, but where the original vegetation is now restricted to small pockets around larger areas of pasture. Native grasslands and grassy woodlands had high fertility and were easily converted to pasture, soon after the European settlement of Tasmania.

The ability of the species to recolonise areas at any distance from extant populations is unknown. The butterfly is a weak flyer, and the probability of recolonising sites, unless suitable habitat corridors exist, appears low. The long-term viability of populations that are now small remnants of once large populations is also unknown, although they are extremely vulnerable to disturbance. If small remnant populations are lost, through overgrazing or fire or clearing, then those sites may never be recolonised.

Grazing

It is difficult to assess accurately the impact of grazing, as the tussock grasses persist in all but the most heavily grazed areas. The long-term survival of the species depends upon the survival of healthy, dense (> 25%) populations of *Poa*. The control of stock-grazing levels on butterfly colonies is the first priority, because, without a reduction in the grazing pressure, many extant colonies will soon be extinct. Conversely, at a number of sites where there has been little or no grazing and where the tussocks have become large and overgrown, there are fewer butterflies than at nearby sites which are lightly grazed. This may be related to the apparent preference of the butterfly to fly around high tussocks rather than over them.

Long-term monitoring of a range of sites is essential in order to quantify the effects of varying grazing pressures on populations of the butterfly.

Plantation Development

In the Northwest Plains region, large areas of *Poa*-dominated grasslands have recently been converted to eucalypt plantations by private timber companies. Further areas will be converted in the future. Some areas within the region have been set aside as reserves, but additional areas of grassland within the plantation program may need to be set aside as reserves for the butterfly, to prevent their local extinction.

Burning

Repeated burning of remnant native grasslands has caused severe decline in population levels in some areas, notably on private land in the East Coast and Tiers, where the traditional management practice has been to burn the grassy forests every two or three years. Anecdotal evidence suggests that in some areas the burning was annual. Burning of these forests is done to encourage "green pick" for stock. The species has persisted in these areas, although at many sites butterfly numbers are now low. A reduction in the frequency of burning is necessary to ensure the survival of the species in these areas. A pattern of mosaic burning, aimed at burning different areas each year on an approximately seven-year cycle, achieves the aim of reducing fuel loads and maintaining grassiness without a loss in productivity or understorey diversity. A longer cycle of mosaic burning would also be more suited to the butterfly.

The season of burning is also important. During the day, the larvae hides in the base of the tussock. Hot fires in summer are more likely to kill them than cooler fires in spring or autumn which leave more of the tussock base intact. Fires during the flight season (March) should be avoided entirely.

CONCLUSIONS

The current parlous state of the butterfly is a reflection of the very poor state of most native grasslands in Tasmania (Kirkpatrick *et al.* 1988). In the Southern Midlands the original vegetation was a mosaic of grasslands and grassy woodlands (Fensham 1989). It is likely that, in the past, the butterfly would not have been restricted to small discrete patches of habitat but, rather, would have been able to roam over extensive areas, wherever tussock grasses were present. The fragmentation and degradation of habitat has caused the gradual decline of the butterfly to its present endangered state.

Fortunately tussock grass can persist, even in the face of heavy grazing, and is only eradicated completely by ploughing. In old pastures, tussock grass is able to re-establish, and some extant colonies could potentially expand simply through control of grazing in adjacent areas, which would allow the tussock grasses to spread.

A recovery plan for the butterfly has been prepared (Neyland 1991) funded by the Australian National Parks and Wildlife Service under the Endangered Species Program. This plan outlines the steps necessary to ensure the long-term survival of the species. Control of stocking rates on butterfly colonies, either through fencing or through reductions in stocking rates, is the key to survival of the butterfly.

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THE PLANTS OF THE TREVALLYN STATE RECREATION AREA, TASMANIA

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(with one table and one text-figure)

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A census of species of all plant groups, excluding free-growing fungi and algae, of the Trevallyn State Recreation Area near Launceston, Tasmania, is presented. The list of 232 species of flowering plants includes 15 species that are either rare or considered to be vulnerable, or are unreserved or poorly represented in state reserves. Although gazetted as a state recreation area, the management policy for the reserve is consistent with the preservation of existing native vegetation.

Key Words: Trevallyn State Recreation Area, vascular plants, bryophytes, lichens, Northern Tasmania, rare species, threatened species.

INTRODUCTION

The Trevallyn State Recreation Area (SRA) lies within 5 km of the centre of the City of Launceston and is the largest reserve near to Tasmania's second largest city, with an area of c. 400 ha. The SRA (fig. 1) is bounded on its western side by Trevallyn Lake, formed by the Trevallyn Dam on the South Esk River. Below the dam, the river flows southeastwards, turning northeastwards at the extreme southern tip of the SRA, ultimately forming the River Tamar at its junction with the North Esk River outside the boundaries of the Reserve. Private property and Reatta Road form part of the northern boundary of the SRA, with the northeastern boundary abutting on houses in the suburb of Trevallyn. At its extreme eastern side, the SRA shares a border with the Cataract Gorge Reserve.

The SRA has a bedrock of Jurassic dolerite. The soils on this have a topsoil that is mostly a brown or grey-brown loam, with a grey, sandy loam subsurface which changes sharply at about 0.3 m depth to a yellow-brown clay (Tasmanian Department of Agriculture 1981). Minor occurrences of lateritic soils are found throughout the area (see, for example, Longman 1964, 1966: 21). The soil depth is extremely variable, being very shallow and stony in some places where rock is exposed at the surface. Generally the soils are well drained, although they can become waterlogged in areas where there is a heavy clay subsoil and little slope (Tasmanian Department of Agriculture 1981).

The elevation of the SRA ranges from c. 25 m to c. 225 m, the terrain undulating considerably throughout the area and presenting a variety of aspects. The area is bordered on its southwestern and southeastern sides by the gorge of the South Esk River, a gorge cut by a stream enlarged by diversion into the drainage basin of the ancestral South Esk by a basalt flow near Evandale (Nicolls 1960).

Prior to 3 June 1980, the date the Trevallyn SRA was proclaimed, much of the area had been used as a farm. The management of the reserve, now carried out by the Parks and Wildlife Service, a division of the Department of Environment and Land Management, pursues a policy of allowing regrowth of native vegetation. However, controlled burning of some areas is undertaken for fire hazard reduction purposes because the reserve is situated on the outskirts of a major urban area. Also, during a severe drought during the mid-80s, cattle were agisted there intermittently.

SURVEY ZONES AND METHODS

For the botanical survey, the area of 400 ha constituting the Trevallyn SRA was divided into four zones to reflect fundamental differences in the various vegetation types present (fig. 1). By far the most extensive vegetation formation in the reserve is dry sclerophyll forest; its predominant large woody species include *Acacia dealbata*, *Eucalyptus amygdalina* and *E. viminalis*, with conspicuous quantities of *Lomandra longifolia* and *Pteridium esculentum* also present as an understorey. A second vegetation type, which may be described as riparian, is found along the gorge of the South Esk River. In addition to having certain common large species such as *Cassinia aculeata* and *Beyeria viscosa* which were less frequently

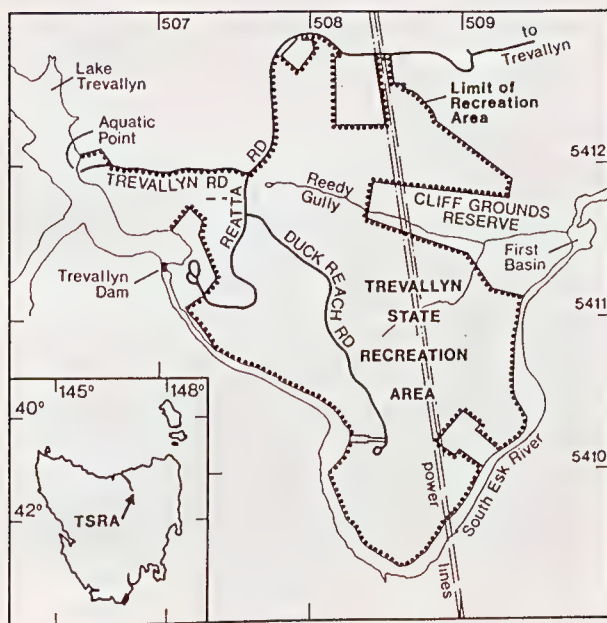


FIG. 1 — Location map for Trevallyn State Recreation Area.

represented in the dry sclerophyll zone, this zone contains a locally abundant stand of *Prostanthera rotundifolia*, a species known only from a few localities in the north and east of Tasmania, and considered to be unreserved and vulnerable (Kirkpatrick *et al.* 1991). Also present in this zone is *Micranthemum hexandrum*, whose occurrence in Tasmania is exclusively northern and eastern (Orchard 1991). A third environment, which contains several fern species (of the Blechnaceae and Dicksoniaceae) not found elsewhere in the reserve, borders a perennial or intermittent creek (Reedy Gully, fig. 1). The fourth zone recognised in this survey is an area cleared of most trees and shrubs underneath the electricity lines that form part of the Hydro-Electric Commission's grid, which includes the Trevallyn Power Station on the Tamar River. This zone contains a large variety of herbaceous species.

Visits to the survey zones were made on a weekly or twice-weekly basis between September 1991 and May 1992. An attempt was made to cover as much of the area as possible, using all of the available tracks and also travelling cross-country wherever the terrain permitted. Species in planted beds along roadsides, landscaped picnic areas and a rubbish tip opposite the commercial Cable Hang Glider installation were omitted from the survey. Aside from these, the survey includes all other introduced species.

RESULTS

Table 1 lists the plant species recorded; it includes 232 species of flowering plants (of which 161 are native to Tasmania, including five endemics), ten fern species, 39 mosses, 18 liverworts and 57 lichens. For the flowering plants and ferns, a measure of abundance (local, rare, occasional, frequent or common) is given for each species in each zone. For the mosses and liverworts, no measure of abundance is given, because positive identification of a species in the field is difficult, but table 1 records the zones in which each species was found. For the lichens, which often require chemical analysis for determination, only the presence of species is recorded. The scientific names of the flowering plants and ferns follow Buchanan *et al.* (1989); those of the mosses follow Dalton *et al.* (1991); those of the liverworts follow Ratkowski (1987). For the lichens, scientific names and authorities are given in full, as there have been many alterations and additions to the checklist previously published by Kantvilas (1989).

DISCUSSION

Among the flowering plants, 15 species are considered to be of interest because of their rareness, vulnerability or unreserved status. Kirkpatrick *et al.* (1991) classified all of Tasmania's native higher plants as to the extent to which they were present in national parks or "equivalent reserves", categories which do not include state recreation areas. Three species, *Brunonia australis*, *Goodia pubescens* and *Prostanthera rotundifolia*, are unreserved anywhere in Tasmania, and a fourth species, *Centipeda cunninghamii*, is reserved only at Lavinia Nature Reserve on King Island. A fifth species, *Myriophyllum integrifolium*, is reserved only at Epping Forest Nature Reserve and is considered to be vulnerable. The remaining ten species, *Hydrocotyle callicarpa*, *Cynoglossum australe*, *Myosotis australis*, *Crassula decumbens*, *Scutellaria*

humilis, *Persicaria prostrata*, *Aphelia gracilis*, *A. pumilio*, *Carex longebrachiata* and *Dichopogon strictus* are accorded the status "r2" by Kirkpatrick *et al.* (1991), which means that they are known to occur in 20 or less 10 km × 10 km National Mappingsquares in Tasmania. Except for *Crassula decumbens*, which is known from five national parks or equivalent reserves, the other nine species are recorded from only one reserve each.

The most diverse families of flowering plants were the grasses (Poaceae) with 30 species (18 native), the daisies (Asteraceae) with 29 species (18 native), the wattles and "pea" flowers (Fabaceae) with 18 species (nine native), and the sedges (Cyperaceae) with 15 species (14 native). Only four orchid species were recorded.

None of the cryptogams was considered to be particularly noteworthy or unusual, with the possible exception of the lichen record reported here as *Bacidia* cf. *millegrana*, which requires comparison with type material to confirm its identity. Most of the species of moss and liverwort grew in moist or shady areas within dry sclerophyll environments. A few are adapted to the very dry conditions that prevail during the summer months, being capable of withstanding desiccation but returning to a healthy appearance once the autumn and winter rains bring moister conditions. The lichens were mainly collected from the bark of trees, with several growing on soil, rocks and stones at ground level. Most species are typical of dry sclerophyll forests in Tasmania. The most common species on trees are the foliose lichens, *Parmelina conlabrosa*, *P. pseudorelicina* and *Flavoparmelia rutidota*, and the tiny crustose species *Buellia disciformis*. On soil, *Heterodea muelleri*, *Cladia aggregata* and species of *Cladonia* predominate, whilst species of *Xanthoparmelia* are common on rocks. As with the bryophytes, lichens were often found growing in moister sites within the dry sclerophyll environment. Hence, the conditions that determine where these species occur are related more closely to the microclimate than to the broad-scale vegetation classification, such as dry sclerophyll, gorge, etc., used here.

Since much of the survey area had been used as a farm prior to 1980, the current composition of the vegetation is undoubtedly vastly different from what it was prior to European settlement. The present management policy of the Parks and Wildlife Service is for minimal interference, allowing for natural regrowth of the vegetation. Nevertheless, because of the reserve's location on the outskirts of Tasmania's second largest urban area, the Service also has the responsibility to reduce fire hazards by occasional burning for fuel reduction. It is possible, however, that increasing wildlife populations will lessen the need for hazard reduction burning to some extent in the future. Another unpredictable factor is the possibility of future periods of severe drought, resulting in a shortage of feed for farm animals. Should that happen, it is possible that the Tasmanian Government may require that the reserve be used for cattle agistment, as it did in the mid-80s. Consequently, it is not possible to guarantee that the vegetation will be allowed to achieve a "climax community" in any sense, nor predict that the diversity of plant species in the reserve will increase in the future.

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TABLE 1
List of species found in Trevallyn SRA

Zones: D, dry sclerophyll; G, slopes of the gorge of the South Esk River; C, Reedy Gully Creek and environs; P, areas cleared underneath electricity power lines.

Abundances: l, local (growing in a few places only, sometimes abundantly); r, only 1–3 plants observed, rare; o, widespread but only occasional; f, widespread and frequent; c, widespread and common.

(I) following a species name indicates that this species has been introduced to Tasmania. All other species are considered to be native. (E) indicates species endemic to Tasmania.

Species	Zones D G C P	Species	Zones D G C P
DICOTYLEDONES		<i>Senecio jacobea</i> (Ragwort) (I)	r r
APIACEAE		<i>Senecio linearifolius</i> (Fireweed)	r r f
<i>Conium maculatum</i> (Hemlock) (I)	l	<i>Senecio minimus</i> (Fireweed)	l
<i>Daucus glochidiatus</i> (Austral Carrot)	r r r	<i>Senecio quadridentatus</i> (Cotton Fireweed)	l r l
<i>Hydrocotyle callicarpa</i> (Pennywort)	f r c	<i>Solenogyne gunnii</i> (Solenogyne)	
<i>Hydrocotyle hirta</i> (Hairy Pennywort)	f	<i>Sonchus asper</i> (Prickly Sow Thistle) (I)	o o
ASTERACEAE		<i>Taraxacum officinale</i> (Dandelion) (I)	o o o o
<i>Arctotheca calendula</i> (Cape Weed) (I)	r	BORAGINACEAE	
<i>Bedfordia salicina</i> (Blanket Leaf) (E)	r	<i>Cynoglossum australe</i> (Hound's-Tongue)	r
<i>Brachyscome</i> sp. (Field Daisy)	r r	<i>Cynoglossum suaveolens</i> (Hound's-Tongue)	r
<i>Carduus tenuiflorus</i> (Winged Slender Thistle) (I)	o o o o	<i>Lithospermum officinale</i> (Gromwell) (I)	r r l r
<i>Cassinia aculeata</i> (Dolly Bush)	o c f r	<i>Myosotis australis</i> (Forget-me-not)	r
<i>Centipeda cunninghamii</i> (Sneezeweed)	l	<i>Myosotis discolor</i> (Forget-me-not) (I)	r
<i>Centipeda minima</i> (Sneezeweed)	l	<i>Myosotis sylvatica</i> (Forget-me-not) (I)	r
<i>Chrysanthemoides monilifera</i> (Boneseed) (I)	l	BRASSICACEAE	
<i>Cirsium vulgare</i> (Spear Thistle) (I)	f o o f	<i>Cardamine hirsuta</i> (Bittercress) (I)	r r r
<i>Cotula australis</i> (Common Cotula)	r	<i>Rorippa dictyosperma</i> (Bittercress)	f
<i>Cotula reptans</i> (Creeping Cotula)	r	BRUNONIACEAE	
<i>Filago gallica</i> (French Filago) (I)	l r	<i>Brunonia australis</i> (Blue Pincushion)	r l
<i>Hypochoeris glabra</i> (Smooth Cat's Ear) (I)	r	CAMPANULACEAE	
<i>Hypochoeris radicata</i> (Flat-weed; Cat's Ear) (I)	o o o o	<i>Pratia pedunculata</i> (Matted Pratia)	r
<i>Lagenifera stipitata</i> (Blue Bottle-Daisy)	o r	<i>Wahlenbergia gymnoclada</i> (Bluebell)	o r
<i>Leontodon taraxacoides</i> (Hawkebit) (I)	f o o c	<i>Wahlenbergia stricta</i> (Bluebell)	o o
<i>Leptorhynchus squamatus</i> (Scaly Buttons)	r	CAPRIFOLIACEAE	
<i>Microseris lanceolata</i> (Native Dandelion)	r	<i>Sambucus gaudichaudiana</i> (Native Elder)	l r
<i>Olearia stellulata</i> (Daisy-Bush)	r r r	CARYOPHYLLACEAE	
<i>Pseudognaphalium luteo-album</i> (Cudweed)	c f c f	<i>Cerastium glomeratum</i> (Sticky Mouse-eared Chickweed) (I)	o o
<i>Senecio glomeratus</i> (Fireweed)	l l	<i>Sagina apetala</i> (Annual Pearlwort) (I)	l
<i>Senecio hispidulus</i> (Scabrid Fireweed)	l l	<i>Stellaria pungens</i> (Prickly Starwort)	r f f

Table 1 cont.

Species	Zones D G C P				Species	Zones D G C P			
CASUARINACEAE					LAURACEAE				
<i>Allocasuarina verticillata</i> (She-Oak)	f	f	f	o	<i>Cassytha melantha</i> (Native Dodder)	o	o	c	o
CONVOLVULACEAE					LINACEAE				
<i>Dichondra repens</i> (Kidney-weed)	f	f	f	o	<i>Linum trigynum</i> (French Flax) (I)	l	l		l
CRASSULACEAE					MYRTACEAE				
<i>Crassula decumbens</i> (Spreading Crassula)	l	l		f	<i>Calytrix tetragona</i> (Fringe Myrtle)			l	
<i>Crassula peduncularis</i> (Purple Crassula)	o			o	<i>Eucalyptus amygdalina</i> (Black Peppermint) (E)	c	c	c	o
DILLENIACEAE					<i>Eucalyptus ovata</i> (Swamp Gum)			l	
<i>Hibbertia hirsuta</i> (Guinea Flower) (E)	l			r	<i>Eucalyptus viminalis</i> (White Gum, Manna Gum)	c	c	c	o
<i>Hibbertia riparia</i> (Guinea Flower)	r	r			<i>Leptospermum lanigerum</i> (Woolly Tea-tree)			f	
DIPSACAEEAE					OLEACEAE				
<i>Dipsacus sylvestris</i> (Teasel) (I)	l				<i>Notelaea ligustrina</i> (Native Olive)			f	o
DROSERACEAE					ONAGRACEAE				
<i>Drosera peltata</i> ssp. <i>peltata</i> (Sundew)	f			c	<i>Epilobium billardierianum</i> ssp. <i>cinereum</i> (Willowherb)			l	
<i>Drosera peltata</i> ssp. <i>peltata</i> var. <i>gracilis</i> (Sundew)	l			o	<i>Epilobium gunnianum</i> (Willowherb)			r	
<i>Drosera pygmaea</i> (Pigmy Sundew)				f	OXALIDACEAE				
EPACRIDACEAE					<i>Oxalis corniculata</i> sens. lat. (Yellow Wood Sorrel)	c	c	c	c
<i>Acrotriche serrulata</i> (Ant's Delight)	o			r	PASSIFLORACEAE				
<i>Astroloma humifusum</i> (Native Cranberry)	o			r	<i>Passiflora cinnabarina</i> (Passion-flower) (I)			r	r
<i>Epacris impressa</i> (Common Heath)	c	o	o	o	PITTOSPORACEAE				
<i>Lissanthe strigosa</i> (Peach Berry)	o				<i>Billardiera scandens</i> (Apple Berry)			r	r
ERICAEEAE					<i>Bursaria spinosa</i> (Australian Prickly Box)			f	c
<i>Erica lusitanica</i> (Spanish Heath) (I)	r			r	<i>Pittosporum bicolor</i> (Cheesewood, Tallow-wood)			r	l
EUPHORBIACEAE					PLANTAGINACEAE				
<i>Beyeria viscosa</i> (Pinkwood)	o	c		f	<i>Plantago coronopus</i> (Buck's-horn Plantain) (I)			o	
<i>Micranthemum hexandrum</i> (Box Micranthemum)				l	<i>Plantago lanceolata</i> (Ribwort) (I)			l	
<i>Poranthera microphylla</i> (Small-leaf Poranthera)	o	o	o	o	<i>Plantago varia</i> (Variable Plantain)			f	r
FABACEAE					POLEMONIACEAE				
<i>Acacia dealbata</i> (Silver Wattle)	c	c	c	o	<i>Navaretia squarrosa</i> (Californian Stinkweed) (I)			r	
<i>Acacia mearnsii</i> (Black Wattle)	f	o	o	r	POLYGALACEAE				
<i>Acacia melanoxylon</i> (Blackwood)	f	c	c	o	<i>Comesperma volubile</i> (Blue Love Creeper)			o	o
<i>Acacia mucronata</i> (Narrow-leaved Wattle)	o	o			POLYGNACEAE				
<i>Bossiaea prostrata</i> (Creeping Bossiaea)	r			r	<i>Persicaria prostrata</i> (Creeping Knotweed)			l	
<i>Cytisus scoparius</i> (Broom) (I)				r	<i>Rumex acetosella</i> (Sheep's Sorrel) (I)			o	o
<i>Daviesia latifolia</i> (Bitter Leaf)	r				<i>Rumex obtusifolius</i> (Broad-leaf Dock) (I)			l	
<i>Genista monspessulana</i> (Canary Broom) (I)				r	PRIMULACEAE				
<i>Goodia pubescens</i> (Silky Clovertree)	l			l	<i>Anagallis arvensis</i> ssp. <i>arvensis</i> (Pimpernel) (I)			o	o
<i>Hovea</i> sp. (Hovea)	r				RANUNCULACEAE				
<i>Indigofera australis</i> (Native Indigo)	r	r			<i>Clematis aristata</i> (Australian Clematis)			o	o
<i>Lotus pedunculatus</i> (Greater Trefoil) (I)	l				<i>Ranunculus lappaceus</i> (Buttercup)			o	o
<i>Lotus subbiflorus</i> (Hairy Bird's-foot Trefoil) (I)	l				RHAMNACEAE				
<i>Lotus tenuis</i> (Slender Bird's-foot Trefoil) (I)	l				<i>Pomaderris apetala</i> (Dogwood, Native Hazel)			f	c
<i>Trifolium dubium</i> (Yellow Suckling Clover) (I)	r	r		r	ROSACEAE				
<i>Trifolium repens</i> (White Clover, Dutch Clover) (I)				l	<i>Acaena echinata</i> (Sheep's Burr)			f	f
<i>Trifolium subterraneum</i> (Subterranean Clover) (I)	l			o	<i>Acaena novae-zelandiae</i> (Buzzy, Biddy-widdy)			f	c
<i>Ulex europaeus</i> (Gorse, Furze) (I)	o	o	o	o	<i>Crataegus monogyna</i> (Hawthorn) (I)			r	r
FUMARIACEAE					<i>Rosa canina</i> (Dog Rose) (I)			r	
<i>Fumaria muralis</i> (Fumitory) (I)	r				<i>Rubus fruticosus</i> (Blackberry) (I)			l	o
GENTIANACEAE					<i>Rubus parvifolius</i> (Native Raspberry)			f	f
<i>Centaurium erythraea</i> (Common Centaury), (I)	f	o	o	f	RUBIACEAE				
<i>Cicendia filiformis</i> (Slender Cicendia) (I)	o			c	<i>Asperula conferta</i> var. <i>conferta</i> (Common Woodruff)			l	
<i>Sebaea ovata</i> (Yellow Sebaea)				r	<i>Coprosma quadrifida</i> (Native Currant)				r
GERANIACEAE					<i>Galium aparine</i> (Cleavers, Goosegrass) (I)			o	o
<i>Erodium moschatum</i> (Musk Storksbill) (I)	o			r	<i>Galium australe</i> (Tangled Bedstraw)			o	o
<i>Geranium potentilloides</i> (Geranium)	c	c	c	c	<i>Galium gaudichaudii</i> (Rough Bedstraw)?			o	o
<i>Pelargonium inodorum</i> (Pelargonium, "Geranium")	o	o			<i>Galium murale</i> (Small Bedstraw) (I)			o	o
GOODENIACEAE					<i>Opercularia ovata</i> (Broad-leaf Stinkweed)			r	
<i>Goodenia elongata</i> (Lanky Goodenia)	l				<i>Sherardia arvensis</i> (Field Madder) (I)			r	r
<i>Goodenia lanata</i> (Native Primrose)	o			r	RUTACEAE				
<i>Goodenia ovata</i> (Parrot's Food)				r	<i>Correa lawrenciana</i> (Native Fuchsia)			l	
HALORAGACEAE					<i>Correa reflexa</i> (Native Fuchsia)			r	o
<i>Gonocarpus tetragynus</i> (Common Raspwort)	c	f	o	o	SALICACEAE				
<i>Myriophyllum integrifolium</i> (Water Milfoil)	l				<i>Salix "fragilis"</i> (Crack Willow) (I)			f	
LAMIACEAE					SANTALACEAE				
<i>Mentha pulegium</i> (Pennyroyal) (I)	l			l	<i>Exocarpos cupressiformis</i> (Native Cherry)			f	f
<i>Prostanthera rotundifolia</i> (Round-leaf Mint-bush)				l	SAPIINDACEAE				
<i>Prunella vulgaris</i> (Self-heal) (I)	o	l			<i>Dodonaea viscosa</i> (Native Hop)			o	f
<i>Scutellaria humilis</i> (Dwarf Skullcap)	r				SCROPHULARIACEAE				
					<i>Gratiola latifolia</i> (Broad-leaf Brooklime)			l	l

Table 1 cont.

Species	Zones D G C P				Species	Zones D G C P			
<i>Parentucellia latifolia</i> (Common Bartsia) (I)				l	<i>Aira caryophyllea</i> (Silvery Hair Grass) (I)	f	o		f
<i>Parentucellia viscosa</i> (Sticky Bartsia) (I)	l			o	<i>Aira elegantissima</i> (Elegant Hair Grass) (I)	f	o	o	o
<i>Verbascum virgatum</i> (Twiggy Mullein) (I)	r			l	<i>Anthoxanthum odoratum</i> (Sweet Vernal Grass) (I)	r			
<i>Veronica calycina</i> (Speedwell)		r			<i>Briza maxima</i> (Quaking Grass) (I)		l		
<i>Veronica gracilis</i> (Speedwell)	o			o	<i>Briza minor</i> (Lesser Quaking Grass) (I)	o			o
STACKHOUSIACEAE					<i>Bromus hordeaceus</i> (Brome) (I)	l			
<i>Stackhousia monogyna</i> (Native Mignonette, Candles)		r	r		<i>Cynosurus cristatus</i> (Crested Dog's-tail) (I)	r	r		r
STYLIDIACEAE					<i>Danthonia caespitosa</i> (Wallaby Grass)	o	r	o	o
<i>Stylidium graminifolium</i> (Trigger Plant)		r			<i>Danthonia dimidiata</i> (Wallaby Grass) (E)	o		o	
URTICACEAE					<i>Danthonia pilosa</i> (Wallaby Grass)	o	o	o	o
<i>Urtica incisa</i> (Nettle)		l			<i>Danthonia racemosa</i> (Wallaby Grass)	o		r	
VIOLACEAE					<i>Danthonia setacea</i> (Wallaby Grass)	o	o	o	o
<i>Hymenanthera dentata</i> (Tree Violet)	l				<i>Deyeuxia quadrisetia</i> (Bent Grass)	o	r		r
<i>Viola hederacea</i> (Ivy-leaf Violet)	c	c	c	c	<i>Dichelachne rara</i> (Plumegrass)	r	l		
MONOCOTYLEDONES					<i>Ehrharta distichophylla</i> (Ricegrass)	c	f	f	f
CENTROLEPIDACEAE					<i>Ehrharta stipoides</i> (Weeping Grass)	o	o	o	o
<i>Aphelia gracilis</i> (Slender Aphelia)	l			l	<i>Holcus lanatus</i> (Yorkshire Fog) (I)	o	o	o	o
<i>Aphelia pumilio</i> (Dwarf Aphelia)	o			o	<i>Paspalum dilatatum</i> (Paspalum) (I)	l			
<i>Centrolepis aristata</i> (Pointed Centrolepis)	l			l	<i>Pentapogon quadrifidus</i> (Five-awned Speargrass)				r
<i>Centrolepis strigosa</i> (Hairy Centrolepis)	o			o	<i>Poa annua</i> (Annual Poa) (I)	o	o	o	o
CYPERACEAE					<i>Poa labillardieri</i> (Tussock Grass)	c	c	c	c
<i>Carex appressa</i> (Tall Sedge)	o	o	o	o	<i>Poa rodwayi</i> (Tussock Grass)	l	l		
<i>Carex gaudichaudiana</i> (Sedge)	l			l	<i>Stipa mollis</i> (Speargrass)		l	r	
<i>Carex inversa</i> (Sedge)	r				<i>Stipa pubinodis</i> (Speargrass)		f	o	o
<i>Carex longibrachiata</i> (Drooping Sedge)	o			o	<i>Stipa stuposa</i> (Speargrass)		o	o	o
<i>Cyperus eragrostis</i> (Umbrella Sedge) (I)	l	l			<i>Themeda triandra</i> (Kangaroo Grass)	f	f	o	f
<i>Cyperus tenellus</i> (Tiny Flat-sedge)	o			o	<i>Vulpia bromoides</i> (Squirrel-tail Fescue) (I)	r	r	r	r
<i>Eleocharis acuta</i> (Common Spike-rush)	l			l	POTAMOGETONACEAE				
<i>Eleocharis sphacelata</i> (Tall Spike-rush)	l				<i>Potamogeton tricarinaris</i> (Floating Pondweed)		l		
<i>Isolepis fluitans</i> (Floating Club-rush)	f			f	TYPHACEAE				
<i>Isolepis platycarpa</i> (Club-rush)	l			o	<i>Typha latifolia</i> (Cats'-tail, Bulrush) (I)	l		l	l
<i>Lepidosperma elatius</i> var. <i>ensiforme</i> (Tall Sword-sedge)	o	o		f	XANTHORRHOEACEAE				
<i>Lepidosperma inops</i> (Little Sword-sedge) (E)	l			l	<i>Lomandra longifolia</i> (Sagg)	c	c	c	c
<i>Lepidosperma laterale</i> (Variable Sword-sedge)	o			o	PTERIDOPHYTES				
<i>Lepidosperma lineare</i> (Narrow Sword-sedge)	r				ASPIDIACEAE				
<i>Schoenus apogon</i> (Common Bog-rush)	c	c	c	c	<i>Polystichum proliferum</i> (Mother Shield-fern)		r	f	
HYPOXIDACEAE					ASPLENIACEAE				
<i>Hypoxis glabella</i> (Yellow Star)	f			c	<i>Asplenium flabellifolium</i> (Necklace Fern)	f	f	f	f
<i>Hypoxis hygrometrica</i> (Golden Weather-glass)	o			r	BLECHNACEAE				
IRIDACEAE					<i>Blechnum nudum</i> (Fishbone Water-fern)			f	
<i>Diplarrhena moraea</i> (White Iris)	r	r		o	<i>Blechnum wattsii</i> (Hard Water-fern)			l	
<i>Gladiolus undulatus</i> (Wild Gladiolus) (I)	l				DENNSTAEDTIACEAE				
JUNCACEAE					<i>Peridium esculentum</i> (Austral Bracken)	c	c	c	c
<i>Juncus articulatus</i> (Jointed Rush) (I)	l	l	l	l	DICKSONIACEAE				
<i>Juncus bufonius</i> (Toad Rush)	f			f	<i>Culcita dubia</i> (Common Ground-fern)			l	
<i>Juncus pallidus</i> (Pale Rush)	o	o	o	o	<i>Dicksonia antarctica</i> (Soft Tree-fern, Manfern)			r	
<i>Juncus procerus</i> (Robust Rush)		l		l	HYMENOPHYLLACEAE				
<i>Juncus subsecundus</i> (Finger Rush)	o	o	o	o	<i>Hymenophyllum cupressiforme</i> (Common Filmy-fern)		l		
<i>Luzula densiflora</i> (Woodrush)	o	o	o	o	POLYPODIACEAE				
LILIACEAE					<i>Microsorium diversifolium</i> (Kangaroo-fern)		o		
<i>Bulbine bulbosa</i> (Bulbine Lily)	o	o	r	r	SINOPTERIDACEAE				
<i>Burchardia umbellata</i> (Milkmaids)	r			r	<i>Cheilanthes austrotenuifolia</i> (Rock-fern)	f	f	o	o
<i>Dianella revoluta</i> var. <i>revoluta</i> (Flax-lily)		o			MOSESSES (Only zones are given, no abundances)				
<i>Dianella tasmanica</i> (Blueberry Flax-lily)			r		AMBLYSTEGIACEAE				
<i>Dichopogon strictus</i> (Chocolate Lily)	r			r	<i>Acrocladium chlamydrophyllum</i>	x	x	x	
<i>Scilla hispanica</i> (Spanish Bluebell) (I)	r				BARTRAMIACEAE				
<i>Wurmbea dioica</i> (Early Nancy)	o	r		c	<i>Bartramia ithyphylla</i>	x	x	x	x
<i>Wurmbea uniflora</i> (Single-flower Wurmbea)			r		<i>Breutelia affinis</i>	x	x	x	x
ORCHIDACEAE					<i>Philonotis tenuis</i>			x	
<i>Diuris sulphurea</i> (Tiger Orchid)		r			BRYACEAE				
<i>Microtis unifolia</i> (Common Onion-orchid)	r	r			<i>Bryum argenteum</i>	x			
<i>Pterostylis pedunculata</i> (Maroonhood)			r	r	<i>Bryum billardieri</i>	x	x	x	x
<i>Thelymitra pauciflora</i> (Slender Sun-orchid)	r			r	<i>Bryum pacytheca</i>	x			
POACEAE					DICRANACEAE				
<i>Agrostis aemula</i> (Blown Grass)	o				<i>Campylopus clavatus</i>	x	x		x
<i>Agrostis avenacea</i> (Blown Grass)	o								
<i>Agrostis capillaris</i> (Brown-top Bent) (I)	o			o					

Table 1 cont.

Species	Zones D G C P				Species	Zones D G C P			
<i>Campylopus introflexus</i>	x	x			MARCHANTIACEAE				
<i>Dicranoloma pallidum</i>	x				<i>Lunularia cruciata</i>	x	x	x	
<i>Dicranoloma billardieri</i>	x				METZGERIACEAE				
<i>Dicranoloma menziesii</i>	x				<i>Metzgeria furcata</i>	x	x		
<i>Eccremidium pulchellum</i> (?)	x		x		PLAGIOCHILACEAE				
DITRICHACEAE					<i>Plagiochila fasciculata</i>	x	x		
<i>Ceratodon purpureus</i>	x		x		<i>Plagiochila strombifolia</i>	x			
FISSIDENTACEAE					RADULACEAE				
<i>Fissidens vittatus</i>	x				<i>Radula buccinifera</i>	x	x		
FUNARIACEAE									
<i>Funaria hygrometrica</i>	x	x			LICHENS (Only species are given, no zones or abundances)				
GRIMMIACEAE					<i>Arthothelium ilicinum</i> (Taylor) P. James				
<i>Grimmia laevigata</i>	x				<i>Bacidia</i> cf. <i>millegrana</i> (Taylor) Zahlbr.				
<i>Grimmia pulvinata</i>	x	x			<i>Buellia disciformis</i> (Fr.) Mudd aggr.				
<i>Racomitrium crispulum</i>	x	x			<i>Candelariella xanthostigmoides</i> (Müll. Arg.) R.W. Rogers				
HYPNACEAE					<i>Cladia aggregata</i> (Sw.) Nyl.				
<i>Hypnum cupressiforme</i>	x	x	x	x	<i>Cladia schizopora</i> (Nyl.) Nyl.				
<i>Isopterygium limatum</i>	x				<i>Cladonia capitellata</i> (J.D. Hook. & Taylor) Church, Bab. var. <i>capitellata</i>				
HYPOPTERYGIACEAE					<i>Cladonia corniculata</i> Ahti & Kashiwadani				
<i>Hypopterygium rotulatum</i>	x	x			<i>Cladonia pyxidata</i> (L.) Hoffm.				
LEMBOPHYLLACEAE					<i>Cladonia ramulosa</i> (With.) Laundon				
<i>Campyochaete arbuscula</i>	x	x			<i>Cladonia rigida</i> (J.D. Hook. & Taylor) Hampe var. <i>rigida</i>				
<i>Lembophyllum divulsum</i> var. <i>divulsum</i>	x	x			<i>Cladonia sulcata</i> Archer var. <i>wilsonii</i> (Archer) Archer				
NECKERACEAE					<i>Flavoparmelia haysomii</i> (Dodge) Hale				
<i>Thamnobryum pumilum</i>			x		<i>Flavoparmelia rutidota</i> (J.D. Hook. & Taylor) Hale				
ORTHOTRICHACEAE					<i>Graphis</i> cf. <i>desquamescens</i> (Fée) Zahlbr.				
<i>Macromitrium acheri</i>	x				<i>Heterodea muelleri</i> (Hampe) Nyl.				
<i>Orthotrichum tasmanicum</i>			x		<i>Heterodermia obscurata</i> (Nyl.) Trevis.				
<i>Zygodon intermedius</i>	x	x	x	x	<i>Hypocnomyce australis</i> Timdal				
POLYTRICHACEAE					<i>Lecidea</i> sp. A				
<i>Polytrichum juniperinum</i>	x		x		<i>Lecidea</i> sp. B				
POTTIACEAE					<i>Lecidea</i> sp. C				
<i>Barbula calycina</i>	x		x		<i>Lecidea</i> sp. D				
<i>Barbula crinita</i>	x	x	x	x	? <i>Lecidea</i> sp.				
<i>Tortula muralis</i>	x				<i>Maronea constans</i> Hepp				
<i>Triglophus papillata</i>	x	x		x	<i>Menegazzia caesiopruinosa</i> P. James				
PTYCHOMNIACEAE					<i>Menegazzia nothofagi</i> (Zahlbr.) D. Galloway				
<i>Ptychomnion aciculare</i>	x	x			<i>Menegazzia platytrema</i> (Müll. Arg.) R. Sant.				
RACOPILACEAE					<i>Menegazzia subpertusa</i> P. James & D. Galloway				
<i>Racomitrium convolutaceum</i>	x	x			<i>Neofuscelia pulla</i> (Ach.) Esslinger				
SEMATOPHYLLACEAE					<i>Parmelia cunninghamii</i> Crombie				
<i>Rhaphidorrhynchium amoenum</i>	x	x	x		<i>Parmelia erumpens</i> Kurok.				
<i>Wijkia extenuata</i>	x				<i>Parmelia signifera</i> Nyl.				
THUIDIACEAE					<i>Parmelia conlabrosa</i> (Hale) Elix & Johnston				
<i>Thuidium furfurosum</i>	x	x	x		<i>Parmelia pseudorelicina</i> (Jatta) Kantvilas & Elix				
<i>Thuidium laeviusculum</i>	x	x			<i>Parmelinopsis afrorevoluta</i> (Krog & Swinscow) Elix & Hale				
LIVERWORTS (Only zones are given, no abundances)					<i>Parmotrema chinense</i> (Osbeck) Hale & Ahti				
AYTONIACEAE					<i>Pertusaria gibberosa</i> Müll. Arg.				
<i>Asterella drummondii</i>	x				<i>Phlyctis subuncinata</i> Stirton				
FOSSOMBRONACEAE					<i>Pseudocyphellaria glabra</i> (J.D. Hook. & Taylor) Dodge				
<i>Fossombronia</i> sp.			x		<i>Pseudocyphellaria neglecta</i> (Müll. Arg.) Magnusson				
FRULLANIACEAE					<i>Punctelia subrudecta</i> (Nyl.) Krog				
<i>Frullania falciloba</i>	x	x			<i>Pyrrhospora laeta</i> (Stirton) Hafellner				
<i>Frullania monocera</i>			x		<i>Ramalina inflata</i> (J.D. Hook. & Taylor) J.D. Hook. & Taylor				
GEOCALYCEACEAE					ssp. <i>inflata</i>				
<i>Chiloscyphus</i> sp.	x				<i>Ramalina inflata</i> ssp. <i>australis</i> G.N. Stevens				
<i>Chiloscyphus biciliatus</i> (?)	x	x			<i>Rimelia reticulata</i> (Taylor) Hale & Fletcher				
<i>Chiloscyphus bispinosus</i> (?)	x				<i>Rinodina</i> sp.				
<i>Chiloscyphus semiteres</i>	x	x			<i>Tephromela atra</i> (Hudson) Hafellner				
JUNGERMANNIACEAE					<i>Thysanothecium scutellatum</i> (Fr.) D. Galloway				
<i>Jamesoniella colorata</i>	x				<i>Usnea confusa</i> Asahina				
LEJEUNEACEAE					<i>Usnea inermis</i> Motyka				
<i>Lejeunea drummondii</i>	x				<i>Usnea oncodes</i> Stirton				
<i>Cheilelejeunea mimosa</i>	x	x			<i>Usnea rubicunda</i> Stirton				
LEPIDOLAENACEAE					<i>Usnea scabrata</i> Taylor ssp. <i>tayloriana</i> G.N. Stevens				
<i>Gackstroemia weindorferi</i>	x	x			<i>Usnea subciliata</i> (Motyka) Swinscow & Krog				
LEPIDOZIACEAE					<i>Xanthoparmelia flaviscentireagens</i> (Gyelnik) D. Galloway				
<i>Lepidozia</i> sp.	x				<i>Xanthoparmelia isidiigera</i> (Müll. Arg.) Elix & Johnston				
					<i>Xanthoparmelia tasmanica</i> (J.D. Hook. & Taylor) Hale				

THE DISTRIBUTION OF COASTAL GROUP LANDHOPPERS (CRUSTACEA: AMPHIPODA: TALITRIDAE) RELATED TO SEA SPRAY AT COX BIGHT, TASMANIA

by Alastair M.M. Richardson

(with four tables and four text-figures)

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Terrestrial amphipod crustaceans from two ecological groups, the coastal group and the forest group, were collected along two transects at right angles to the shoreline at Cox Bight, southwestern Tasmania. The transects were placed on either side of Point Eric to ensure that one was more sheltered from seaspray, in order to examine the hypothesis that the distribution of coastal group landhoppers is controlled by the inland penetration of ionic precipitation.

Coastal species extended twice as far inland on the exposed transect, and their distribution on both transects correlated strongly with raised levels of sodium in the soil, providing good circumstantial support for the hypothesis. The study highlights the ecological importance of the coastal zone in the World Heritage Area. Further studies should examine the effect of manipulating soil ion levels on the distribution of coastal species.

Key Words: Western Tasmania, landhoppers, Talitridae, ionic precipitation.

INTRODUCTION

The Tasmanian terrestrial amphipod fauna can be divided into three ecological groupings: the eastern forest group, the western forest group and the coastal group (Friend 1987a), depending on their distribution. The coastal group comprises species which, although fully terrestrial in other respects, are restricted to a narrow zone immediately above the high tide mark. Friend (1987a) records four species in this group, but recent collections have revealed undescribed species from the coastal zone in the genera *Keratroides*, *Austrotroides* and *Tasmanorchestia*, raising the number of species in the group to at least seven (Friend 1987b, Richardson & Swain 1988, 1990, Richardson *et al.* 1991).

Richardson *et al.* (1991) described the fine-scale distribution of landhoppers above the high tide mark on transects at South Cape Bay, Mulcahy Bay and Hibbs Bay, on the south and west coasts. They recorded ten species of landhoppers, including four coastal group species. They found that species in the coastal group extended between 30 and 50 m inland at South Cape Bay, but over 70 m (the full extent of the transect) inland at Hibbs Bay. Although they were unable to demonstrate any relationship between the distribution of coastal group species and the Na content of the substrate at South Cape Bay (the only site where soil samples were collected), the greater inland penetration of the coastal group species at Hibbs Bay, which is more exposed to westerly winds than South Cape Bay, suggests that ion precipitation may control their distribution.

This study aims to demonstrate, indirectly, a relationship between ionic precipitation and the distribution of coastal group landhoppers at Cox Bight, a few kilometres southeast of Melaleuca. It was not possible to make measurements of ion precipitation, and the actual rates of precipitation will be strongly related to weather conditions; but, as an alternative, soil concentrations of Na were used as a measure of ion precipitation. It was assumed that sea spray will penetrate further inland where the shore is more exposed to westerly winds. Thus, the westward and eastward-facing sides of Point Eric, a relatively high, rocky point which

separates the two halves of Cox Bight, might be expected to receive different amounts of ion precipitation, according to their exposure. The hypothesis being examined here (Friend 1987a, b, Richardson *et al.* 1991) is that coastal group amphipods will penetrate further inland where ionic precipitation, as estimated by soil Na levels, penetrates further inland.

METHODS

Cox Bight is a deeply indented bay in the south coast of Tasmania, about 8 km southeast of the Melaleuca airstrip. The bay is divided into two by Point Eric, a rocky promontory which reaches a height of 40–80 m a.s.l. The bay faces almost due south.

At the top of the beach there is a low dune ridge of varying height, and immediately behind it a band of low (< 6 m) coastal woodland, similar to the NIT0 community of Kirkpatrick *et al.* (1988), dominated by dogwood, *Pomaderris apetala*, and *Eucalyptus nitida*, with an understorey of cutting grass, *Gahnia grandis*, laurel, *Anopterus glandulosus*, bracken, *Pteridium esculentum* and other ferns. This woodland band is 40–60 m deep and then gives way, via a fairly sharp ecotone of *Melaleuca squarrosa*, to a wet heathland variously dominated by buttongrass, *Gymnoschoenus sphaerocephalus*, *M. squamea* and other heathy shrubs, close to the B1a community of Jarman *et al.* (1988). The overall height of this heathland community declines further inland, as the ground rises. There are occasional small copses of low *E. nitida*, the B12 community of Jarman *et al.* (1988).

Two transects were laid out on either side of Point Eric, one to the east ("east transect"), the other to the west ("west transect"), with their starting points at approximately DM388843 and DM385842, respectively (Tasmap 1:100 000 Sheet 8111, *Old River*). The transects ran from immediately above the high tide mark directly inland, at right angles to the tideline. The east transect was 150 m long, but the west transect was restricted to 106 m by an outcrop of large rocks.

At 2 m intervals along each transect, pitfall traps were set. Each trap consisted of a plastic drinking cup of 50 mm diameter and 100 mm depth, let into the soil so that their lips were flush with the soil surface. A plastic Petri dish lid was supported on three twigs over each trap to exclude rainwater, and 5–10 ml of saturated picric acid was placed in each as a non-volatile preservative. Identical traps were used in the earlier study by Richardson *et al.* (1991).

The traps were left in place for 13–14 days, and the catch was then emptied from each trap into a labelled vial containing 70% ethanol. At each trap site, a sample was taken from the surface soil, after the leaf litter layer had been removed. The soil samples were stored in Clipsal™ bags and transported within 3–4 days to the laboratory, where they were stored in a deep freeze.

The landhoppers were identified, using Friend's (1987a) key and collections made in the area previously (Richardson & Swain 1990); the numbers of adult males, females and juveniles were counted. The moisture content of the soil samples was calculated after drying for 48 h at 110°C. Subsamples of the dried soil were ashed at 450°C for 4 h and reweighed to calculate weight loss on ignition. A fixed weight (1 g) of dry soil was mixed with 100 ml of distilled

water and allowed to stand for 24 h. The Na content of the supernatant was measured by flame photometry.

RESULTS

Approximate profiles of the transects and the distribution of plant communities along them are shown in figures 1 & 2. The west transect rises more quickly and to a slightly greater height than the east transect, but the vegetation pattern on both transects is effectively the same, although the belt of coastal woodland extends further inland on the western transect. Of the soil parameters, soil moisture and weight loss on ignition show little evidence of systematic variation along the transects. Soil moisture tends to be lower on the first 30 m of the east transect and the first 20 m of the west transect, probably reflecting the sandier nature of the soils there.

Figures 3 & 4 show the distribution of amphipods in relation to the transect profiles and the Na content of the soil. The amphipods have been grouped into the coastal group and forest group species (table 1). Because the abundances of coastal group animals at the seaward ends of

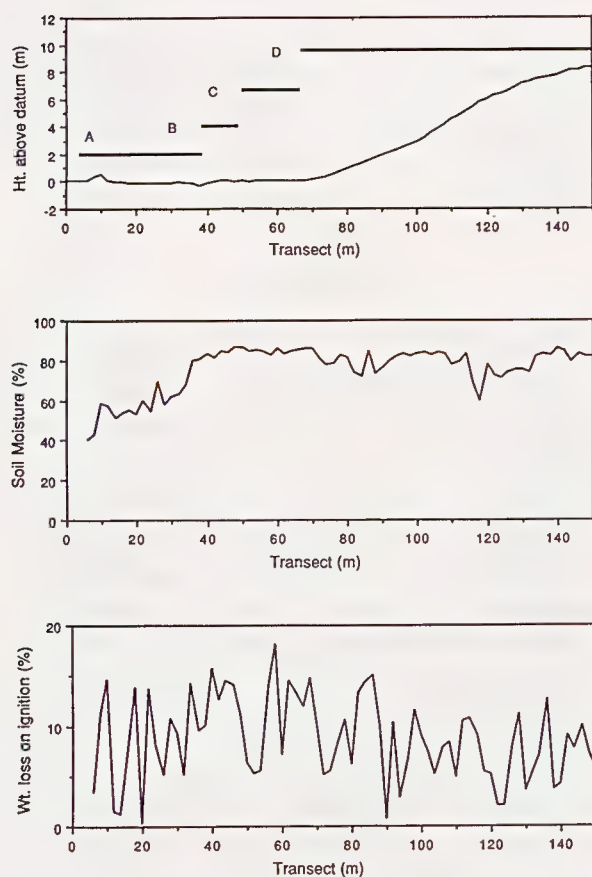


FIG. 1 — Profile of the sheltered transect, to the east of Point Eric, showing the vegetation communities, and the levels of soil moisture and organic content (as weight loss on ignition) along the transect. A = 3 m high coastal woodland with *Eucalyptus nitida*, *Melaleuca squarrosa*, *Gahnia grandis* and bracken; B = 1.5 m tall *M. squarrosa*; C = 1 m tall *M. squarrosa*; D = 0.75 m tall heathy sedgeland with buttongrass and woody shrubs, and a small copse of *E. nitida*.

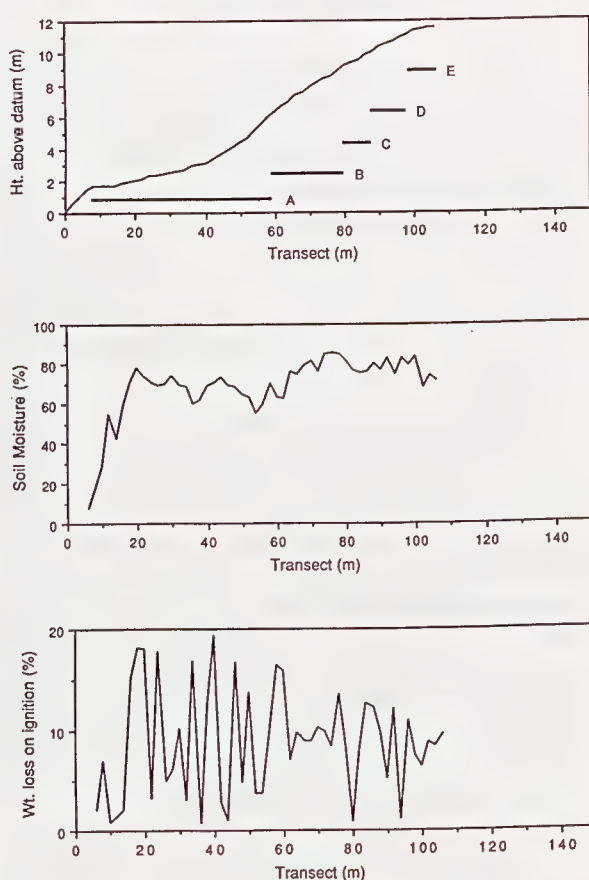


FIG. 2 — Profile of the exposed transect, to the west of Point Eric, showing the vegetation communities, and the levels of soil moisture and organic content (as weight loss on ignition) along the transect. A = 6 m high coastal woodland with *Eucalyptus nitida*, *Pomaderris apetala*, *Anopterus glandulosus* and *Gahnia grandis*; B = 1 m tall *E. nitida*, *Melaleuca squamea* and buttongrass; C = 0.5 m tall *M. squamea*; D = 1 m tall heathy sedgeland with buttongrass and woody shrubs; E = rock outcrop with a small copse of *E. nitida* and *M. squarrosa*.

the transects were very much greater than those inland, the catches have been expressed as logarithms. Seven species of amphipods were present, three from the coastal group and four from the forest group (table 1). *Keratroides vulgaris* only appeared on the west transect, where it was rare.

On the east transect the coastal group species extended 24 m inland, or about half the depth of the coastal woodland. Forest group species first appeared 16 m inland, and no animals of either group were caught between 32 and 48 m, in the inland third of the coastal woodland and the ecotone with the heathland. Forest group species were found all along the remaining length of the transect.

On the west transect the coastal group extended to 52 m inland, and apart from a single specimen of *Neorchestia plicibranchia* at 38 m, the forest group species only appeared from the 50 m mark. There was no evidence of a gap in amphipod distribution at the landward edge of the coastal woodland on the west transect.

Soil sodium levels were a little higher on the seaward half of the exposed west transect than on the east transect, but on both there was a trend for soil Na content to decline on the inland part. In order to test whether there were significant differences between the Na content of the soil in different

parts of the transects, each was divided into three sections: the section with coastal amphipod species only, with mixed coastal and forest species, and with forest species only. The Na content of the soil samples collected at each trap in each of these sections was compared, using a single factor analysis of variance. Soil moisture and weight loss on ignition were treated similarly (tables 2, 3 & 4).

The sodium content of the soil in the section occupied by the coastal species is significantly higher than in the forest species section on both transects. Soil moisture also varies significantly between the sections, increasing from the coastal section to the forest group section.

DISCUSSION

The results of this study are consistent with the hypothesis that reduced ionic precipitation limits the landward penetration of coastal landhoppers. In a preliminary investigation of landhopper distributions at Cox Bight, Richardson & Swain (1990) found that coastal landhoppers extended a similar distance inland on a transect to the west of Point Eric. But on a "sheltered" transect at the western end

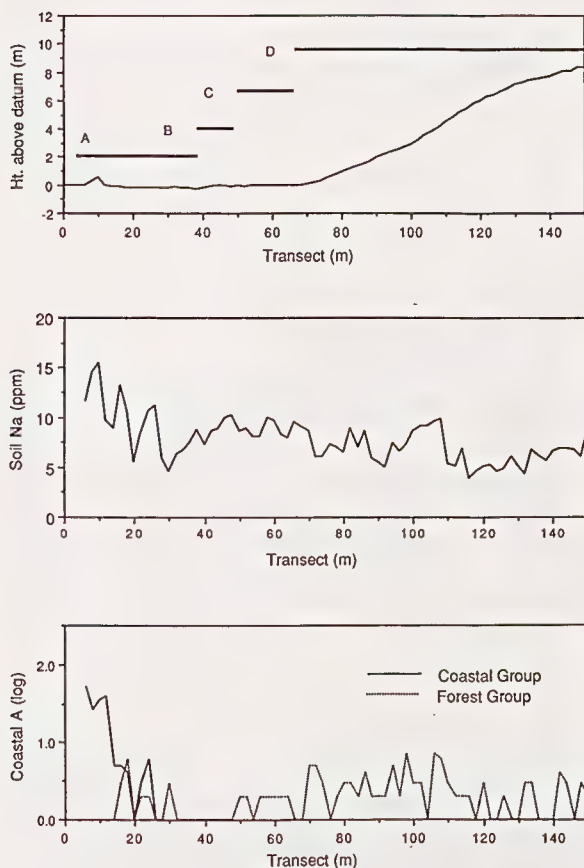


FIG. 3 — The sheltered east transect, showing the concentration of soil Na along the transect and the distribution of coastal and forest group amphipods. Vegetation zones as fig. 1.

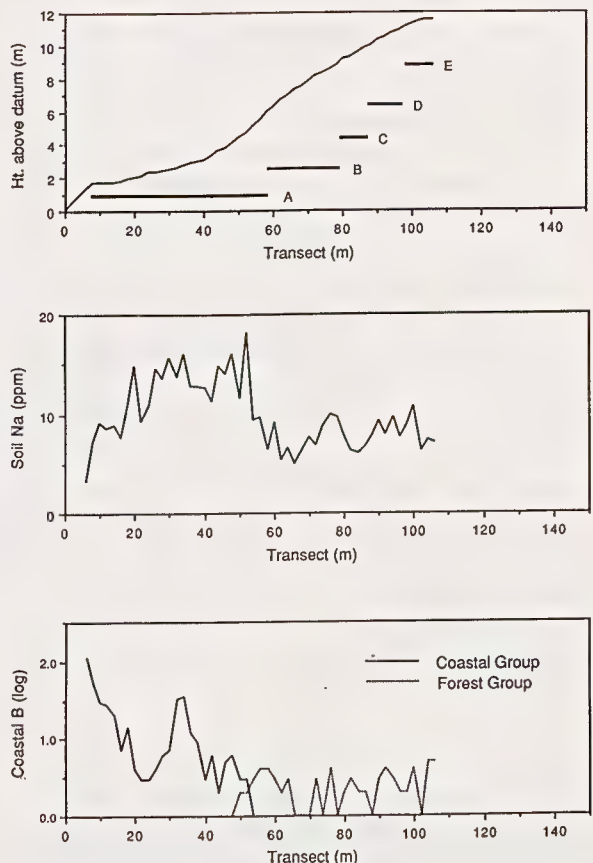


FIG. 4 — The exposed west transect, showing the concentration of soil Na along the transect and the distribution of coastal and forest group amphipods. Vegetation zones as fig. 2.

TABLE 1
Landhoppers (Amphipoda: Talitridae) collected on the Cox Bight transects

	Coastal group	Forest group
East transect	<i>Austrotroides maritimus</i> <i>Tasmanorchestia</i> sp. 3 <i>Keratroides rex</i>	<i>Neorchestia plicibrancha</i> <i>Austrotroides leptomerus</i> <i>Orchestiella neambulans</i>
West transect	<i>Austrotroides maritimus</i> <i>Tasmanorchestia</i> sp. 3 <i>Keratroides rex</i>	<i>Neorchestia plicibrancha</i> <i>Austrotroides leptomerus</i> <i>Orchestiella neambulans</i> <i>Keratroides vulgaris</i>

TABLE 2
Analysis of variance of soil Na content* from Point Eric
Treatments are sites with coastal amphipods only, with coastal/forest species and with forest species only:
A = east transect, B = west transect

	Sum of squares		DF		Mean square		F-ratio		Prob.	
	A	B	A	B	A	B	A	B	A	B
Among	0.226	0.381	2	2	0.113	0.191	11.9164	16.9091	0.00005	<0.00001
Within	0.665	0.541	70	48	0.009	0.011				
Total	0.891	0.922	72	50						

Treatment means (log ppm Na)

Coastal		Coastal/forest		Forest	
A	B	A	B	A	B
1.105	1.058	1.012	1.169	0.905	0.937

Multiple comparisons

Comparison	Difference		Standard Error		Q-value	Critical	A	B
	A	B	A	B				
Forest v coastal	0.201	0.121	0.032	0.024	6.266†	5.094†	3.387	2.844
Forest vs coastal/forest	0.107	0.232	0.032	0.030	3.351†	7.661†	2.821	3.420
Coastal/forest vs coastal	0.093		0.044		2.142		2.821	
Coastal vs coastal/forest		0.111		0.033		3.410†		2.844

* ppm, transformed to $\log_{10}(x+1)$.

† significant.

of the bay, *Keratroides rex* extended about 80 m inland, further than on either of the transects examined here. However, no soil Na levels were measured on the 1990 transects, and the vegetation at the far western end of the bay differs significantly from the Point Eric transects, with mature mixed forest immediately behind a narrow belt of coastal woodland. Richardson & Swain (1990) concluded that the 1990 observations did not provide any conclusive evidence about the role of ionic precipitation.

The present observations can only provide circumstantial evidence of a relationship between ionic precipitation levels and the inland penetration of coastal group amphipods. Firstly, the relationship between soil Na levels, measured at

an instant, and the rate of ionic precipitation is likely to be only very approximate, since the levels at any given time will depend not only on the rate of input, but also on interception by the vegetation and the rate of loss from the soil through leaching. Richardson *et al.* (1991) demonstrated a correlation between soil Na concentration and weight loss on ignition and suggested that increasing organic content would slow the leaching rate of ions. The organic content of the soil on these transects (as estimated weight loss on ignition) was lower and more variable than that measured by Richardson *et al.* (1991) at South Cape Bay and Hibbs Bay, but it did not appear to vary significantly between the transects. There was no strong correlation between organic

TABLE 3
Analysis of variance of soil moisture data* from Point Eric
Treatments as table 2: A = east transect, B = west transect

	Sum of squares		DF		Mean square		F-ratio		Prob.	
	A	B	A	B	A	B	A	B	A	B
Among	2411.503	1341.402	2	2	1205.751	670.701	60.3242	9.1777	<0.00001	0.00049
Within	1399.149	3507.819	70	48	19.988	73.080				
Total	3810.652	4849.221	72	50						

Treatment means (% soil moisture)

Coastal		Coastal/forest		Forest	
A	B	A	B	A	B
44.904	48.777	47.958	55.254	63.066	60.315

Multiple comparisons

Comparison	Difference		Standard Error		Q-value		Critical	
	A	B	A	B	A	B	A	B
Coastal v forest	18.162	11.538	1.469	1.907	12.365†	6.050†	3.387	3.420
Coastal vs coastal/forest	3.054	6.476	1.999	2.617	1.528	2.474	2.821	2.844
Coastal/forest vs forest	15.108	5.062	1.469	2.433	10.286†	2.080	2.821	2.844

* %, transformed to arcsine.

† significant.

TABLE 4
Analysis of variance of weight loss on ignition data* from Point Eric
Treatments as table 2: A = east transect, B = west transect

	Sum of squares		DF		Mean square		F-ratio		Prob.	
	A	B	A	B	A	B	A	B	A	B
Among	62.921	52.560	2	2	31.461	26.280	1.3917	0.7040	0.25448	0.50401
Within	1582.408	1791.780	70	48	22.606	37.329				
Total	1645.330	1844.340	72	50						

* %, transformed to arcsine.

content and Na content ($r = 0.32$, $n = 73$ for the east transect; $r = 0.031$, $n = 51$ for the west transect).

Secondly, there is no unequivocal way of deciding between conflicting explanations of the coastal species' distribution. Thus, their distribution could be controlled by soil moisture, which also varies systematically between the transect sections, and, of course, there may be other controlling factors which have not been identified.

It seems unlikely that the distribution of the coastal group is linked to vegetation patterns, since their landward limit does not coincide with the most obvious sharp change in the vegetation, the woodland/heathland ecotone. On both transects, the coastal species die out before the landward edge of the woodland. The diet of landhoppers is generally thought to be unspecialised (Morton & Richardson 1984)

and they show no obvious linkage to major vegetation types (Richardson 1991), so the change in litter composition is unlikely to affect them. But the absence of any major change in amphipod species at the woodland edge also suggests that the changes in microclimate which occur at that point are not important in controlling amphipod distributions.

The circumstantial evidence that ionic precipitation controls the coastal species distribution is strong. Their inland penetration on the western side of Point Eric is twice that on the sheltered eastern side, just a few hundred metres away, and their distribution on both transects correlates strongly with soil Na levels. The hypothesis could be examined further by a series of transects at a stretch of coastline where (a) there is a similar vegetation pattern, preferably

forest, behind the shore; and (b) the degree of exposure (and thus ionic precipitation) changes steadily. Another, and more rigorous approach would be to manipulate the input of ions into the soil with a view to extending the distribution of coastal species. Similarly, transplanting populations of coastal species increasing distances inland would also provide strong evidence.

The relationship between the forest and the coastal species on these transects is interesting, in that the forest species did not approach as close to the shore as they did at South Cape Bay or Hibbs Bay. At South Cape Bay, the forest species *Mysticotalitrus tasmaniae* was present almost from the seaward limit of the distribution of the coastal species while, at Hibbs Bay, *Keratroides vulgaris* approached to within 5 m of the seaward edge of the coastal species distribution. Neither of these species was common on the Point Eric transects. On the South Cape Bay and Hibbs Bay transects, the coastal vegetation was backed by forest rather than heathland, which may have provided a greater supply of forest species.

The Tasmanian landhopper fauna is apparently more diverse than any other worldwide; no other regional fauna has been shown to include species restricted to the immediate coastal zone. While the existence of halophilic land plants is well known, few examples of terrestrial groups of animals with distributions restricted to the coast have been recorded. A further Tasmanian example can be seen in the landsnail *Bothriembryon tasmanicus*, which is only found very close to the coast (Dartnall 1972, A.M.M. Richardson, pers. obs.), and other examples might be expected among the oniscoid isopods, since coastal species are known in the British fauna (Harding & Sutton 1985, Hopkin 1991).

This study again highlights the significance of the near coastal zone in the Western Tasmania World Heritage Area (Friend 1987b, Harris *et al.* 1993). The combination of the ecological and phylogenetic diversity in the talitrid fauna, and the undisturbed transitions from sea to land in the area, are a biological resource which is very rare or even unavailable elsewhere in the world.

ACKNOWLEDGEMENTS

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THE FOUNDATION YEARS OF THE ROYAL SOCIETY OF TASMANIA, 1843–86

by Gillian Winter

(with three plates)

being the text of a talk delivered at the Annual General Meeting of the Society in its Sesquicentenary Year.

WINTER, G.A., 1993 (31:viii): The Foundation years of the Royal Society of Tasmania, 1843–86. *Pap. Proc. R. Soc. Tasm.* 127: 61–66. ISSN 0080-4703. Tasmaniana Library, State Library of Tasmania, 91 Murray Street, Hobart, Tasmania, Australia 7000.

The early history of the Royal Society is of an organisation broadly based in its scientific activity: developing and administering the Colonial Gardens in Hobart; providing a forum for papers, both practical and scientific; publishing; building a library through the exchange of its publications; and establishing a museum through donations and exchange. Involving both local people and many international corresponding members, the Society was the means by which the scientific world could learn about Tasmania and the local community could learn about European scientific developments and also be informed about local environmental issues.

Key Words: Royal Society of Tasmania, scientific societies, scientific history.

INTRODUCTION

The Royal Society of Tasmania was the first Royal Society to be established outside the United Kingdom. Perhaps of even more interest than its age, however, is the evidence that its early activities were broader in scope than any other scientific body in Australia in the mid- and late-nineteenth century.¹ [Notes will be found at the end of the paper.]

It was set up to administer the Colonial Gardens. After a modest beginning, it soon moved into a period of vigorous activity, branching out to establish a Museum and Library. To build up these three institutions, the Society contacted numerous international bodies and countless individuals, both at home and abroad, arranging for the exchange of items or soliciting donations.

Scientific societies were established in other colonies in the decades after the 1840s, but they were slow to publish regular journals and build up their libraries through exchange. In no other colony were the botanical gardens under the control of a scientific society, and in Victoria and Queensland, where museums were established as adjuncts to scientific societies, control very soon passed to the University of Melbourne and the Queensland Government, respectively. Other Australian societies had international contacts, but Tasmania's contacts were more numerous because of its diverse activities. The Museum and Gardens also gave local residents a greater opportunity to participate more fully in the Society's work than other societies could provide. Tasmanian members could be donors if they could not deliver a paper. Many, indeed, considered the administration and development of the Gardens and Museum the chief activities of the Society.

The government grant, given to the Society from its inception, was designed to support the Museum and Gardens, but it was often insufficient for the adequate maintenance of the collections and left nothing for enlarging them. This was done chiefly by donation and exchange. The Society carefully husbanded its resources and applied judicious pressure to gain financial, and other, help for its growing collections. At times it suffered from severe financial difficulties and its very existence depended on the initiative, energy and perseverance of a few members.

At first, members of the Society enjoyed a number of special privileges relating to the Gardens and Museum but these were gradually revoked and the Society increasingly saw itself as the trustee and administrator of two public institutions. (Even the Library was, in the beginning, planned as the nucleus of a public library.) It is hardly surprising, then, that in 1885 the Society arranged to have the Museum and Gardens incorporated and permanently endowed as public bodies.

The Fellows of the Society met regularly to read and discuss scientific papers which were published and had a worldwide circulation. Contributions were drawn from all over Australia and even overseas, as the Society had a number of active Corresponding Members. A lot of original material, particularly relating to Australia's flora, fauna and geology, was first brought forward at meetings of the Society. Many other papers were intended to increase colonists' knowledge of their new country in the hope that this information could be turned to profitable advantage. This emphasis on the "practical" aspects of science is understandable.

The Society was "exclusive" in the sense that it was started under, and continued to enjoy, vice-regal patronage and many of its members were high-ranking civil servants, wealthy graziers, or clergymen. Its membership, however, could not be compared with that of European societies, which were largely composed of scientists. Without even a university to provide a trained nucleus of scientists, the Royal Society depended on amateurs (some of whom were particularly gifted men) and a few scientifically trained men in government employment to keep it going. It was open to anyone who was interested in science, open in fact to anyone who cared to belong. For some it was an agreeable "club" to which many of their friends belonged, and which provided discussions which were both "educational" and enjoyable.

The years to 1863 were those of great activity, successful but presenting financial problems because the Society overcommitted its resources. The next twenty years were times of consolidation and solid achievement. An overall examination of the history of the first forty years of the Society clearly shows that it was the channel of communication through which the world could learn more

about Tasmania's natural history and scientific endeavours. It was also the means by which people in the colonies were made aware of European scientific developments. But it also undertook a number of tasks which are now the responsibility of other bodies, usually government departments. They include: meteorology, industrial development, tourism, immigration, public health, agriculture, mapping and land surveying, fisheries, and scenery and wildlife preservation.

PRECURSORS OF THE SOCIETY

The foregoing introductory remarks on the foundation years of the Royal Society (1843–86) summarise the achievements and significance of these early years. The establishment and the operations of the Society during this period, particularly in relation to its three-fold responsibility (the Gardens; the Museum; the presentation and publication of scientific papers), deserve more detailed examination.

First, perhaps, some consideration of the men who enabled a Royal Society to be formed in Hobart Town, Van Diemen's Land in 1843. On the title page of the Minute Book for 1841² of the immediate forerunner of the Royal Society, the Tasmanian Society, is a charming vignette of a platypus, captioned "all things are queer and opposite". It was this recognition by some settlers — that they were not only living in a century of unparalleled interest in scientific matters, but were living in a country that offered evidence of significant variations from the European natural world — which gave them a sense of responsibility to examine and record the antipodean environment. There were, too, the "practical" men of science who wished to pool their growing knowledge of the colony to promote agriculture and industry. There were others who saw science, like literature and art, as a unifying agent in the community, turning men's attentions from politics and the pursuit of wealth, which were seen as divisive. And, of course, there were the acclimatisers, who represent that curious amalgam of scientific curiosity, sentiment and greed which resulted in such ecological and economic disasters as the introduction of the rabbit — as well as such benefits as the salmon. All these men were, through the membership of successive scientific bodies in Hobart, part of a "scientific tradition", albeit a primitive one.



PLATE 1

Old Government House, Macquarie Street, Hobart, where the Society first met on 14 October 1843. Watercolour by Owen Stanley, 1840–41. (Royal Society Collection, held at the Tasmanian Museum and Art Gallery, Hobart.)

The Van Diemen's Land Agricultural Society, established mid-1821 under the presidency of Lieutenant-Governor Sorell, may have had as its main aims the combating of sheep stealing and the raising of the level of animal husbandry in the colony but it was the first "scientific" society in Australia.

Dr John Henderson founded the Van Diemen's Land Scientific Society in 1829, under the patronage of Lieutenant-Governor Arthur, modelling it upon the colonial medical and scientific societies he had encountered in India. He aimed to conduct local scientific experiments and send specimens to scientists in Europe, and he quickly gathered 100 members for his Society. But he soon quarrelled with John Burnett (his Society's Vice-Patron and the Colonial Secretary) and found it expedient to depart for New South Wales.

The third of the Royal Society's forerunners — the Tasmanian Society — was founded by Lieutenant-Governor Sir John Franklin, a Polar hero and a member of English scientific societies, who found that his English correspondents were keenly interested in information about the remote colony he was administering. He presided regularly at meetings (held at Government House), financed the publication of the *Tasmanian Journal*, and welcomed visiting scientists (who included the explorer Count Strzelecki; the ornithologist John Gould; the Antarctic explorers James Ross and Francis Crozier and their French counterpart Dumont d'Urville). As with education and the arts, Sir John and Lady Franklin were committed to stimulating local scientific endeavours to inform and uplift the intellectual and moral character of the community.

ESTABLISHMENT OF THE SOCIETY

Sir John Eardley-Wilmot, Franklin's successor, set up the Van Diemen's Land Horticultural and Botanical Society — later the Royal Society — because he felt that he could not maintain the Colonial Gardens at his own expense but did not want to see them abandoned. The Society, which was to administer the Gardens, financed by a Government grant, was to operate under rules based on the Linnaean and Horticultural Society in England. The Governor sought Royal patronage for this new body. Eardley-Wilmot had accepted presidency of the Tasmanian Society but then appeared to decide that it should be the nucleus of his new Society. The 37 resident Tasmanian Society members were entitled to be among the first fifty foundation Fellows of the Society. But they objected to having to pay an entrance fee and all but five (and many of the invited prospective new members) walked out of the initial meeting in October 1843. Eardley-Wilmot was left with 18 people for his new Society.

The Society's aim was "to develop the physical character of the Island and illustrate its natural history and production".³ Under the 1843 rules Fellows had access to the Gardens, Museum and Library and might take visitors to these places. Ladies were to be admitted as Fellows "upon the same terms, with the same privileges and under the same regulations in all respects as gentlemen".⁴

Administratively, the period from 1843–48 may be seen as one where the Society's activities were concentrated on overseeing the management and development of the 14 acres (5.67 ha) of Gardens; refining the rules for the regulation of the Society; and reaching agreement with the rival Tasmanian Society. Her Majesty agreed to be the Society's patron and

the Royal Society of Van Diemen's Land for Horticulture, Botany and the Advancement of Science was a reality from September 1844.

But its pre-eminent scientific status was not recognised by all local people. Botanist R.C. Gunn, one of the luminaries of this early period (the only Tasmanian in the nineteenth century to be made a Fellow of the English Royal Society), claimed in 1845: "The Royal Botanical Society of Van Diemen's Land will go to the devil"⁵ and said of the Tasmanian Society now based in Launceston: "Science being republican, we have got rid of all vice-presidents, etc and flourish alike as humble members".⁶

Under pressure from Lieutenant-Governor Denison, however, the Royal Society made it easier from 1848 for members of the Tasmanian Society to join and, although no formal amalgamation took place, within eighteen months all active resident members had transferred to the Royal. Initially, the Society made little progress because it did not have a permanent paid Secretary although, had the Government been willing to increase its grant in 1844, the young Joseph Hooker was willing to return to the colony and fulfil the role. But the £300 salary was not forthcoming. Instead, F.W. Newman, the new Superintendent of the Gardens, was appointed. Governor Eardley-Wilmot objected to a "practical botanist and gardener": He required someone of "superior education, and scientific and literary acquirements".⁷ His was not a horticultural but a scientific society. He urged the Society to action, and it undertook to hold monthly meetings to read and discuss papers, although one only was read in 1846. A cottage at the gardens was set up as a Museum, reading and meeting room and donations of natural history specimens and books were sought from English scientific societies.

WILLIAM DENISON'S CONTRIBUTION

The spur to greater action, however, was the man who has been described as "the great resuscitator of scientific societies"⁸: Lieutenant-Governor Sir William Denison. He appointed Dr Joseph Milligan as secretary, ensuring that he had another civil post so that his salary from the Society need not be large. Milligan's reports on the coal fields of Tasmania — part of his government work — were read to the Society and became the first papers it published.

From the time Milligan became Secretary the Society began to function as a genuine scientific body and he was to remain active in the organisation for twelve years. Denison wrote to a friend: "I have succeeded in making a society, which had been nominally established several years, perform some work, and I hope to be able to forward home a specimen of its labours shortly."⁹

Sorell, Arthur, Franklin and Eardley-Wilmot had all been associated with different scientific societies but Denison worked within the existing Society: he gave papers frequently and was a prolific donor and was justly lauded for his activity, generosity and enthusiasm.

It was Denison who was behind the Society's plan to send Tasmanian specimens to the Great Exhibition in London in 1851. It became a public undertaking but the Society acted as the recipient for specimens and arranged for a local exhibition before they were dispatched to England. Tasmania was said to have sent more exhibits, in proportion to its size and population, than any other British colony. Under the

Society's arrangements many of the specimens were given to the British Museum and the Linnaean Society after the Exhibition.

ACTIVITIES OF THE SOCIETY

In 1856 the Society sent products to the Paris Exhibition, a selection which was consciously chosen to appeal to potential immigrants. The Society also reprinted a pamphlet written by Denison for intending emigrants and distributed to public institutions in England lithographs of Hobart by artist Knud Bull, to publicise the colony. The Society contributed to a permanent exhibition of colonial products in London's Crystal Palace — all with the intention of promoting Tasmania abroad.

At the same time issues of local concern were pursued by the Society. It lobbied for the establishment of a meteorological observatory; a public time signal; an electric telegraph line across the island; the improvement of Queen's Domain; the preservation of trees on Mt Wellington; the extermination of the rabbit and codlin moth; the introduction of salmon; and the cessation of the pollution of the Derwent by tar from the gas works and refuse from the slaughterhouse. It was at meetings of the Society that, among other things, the telephone, the phonograph and the microphone were first demonstrated.

The Society's interest in the Tasmanian aborigines encompassed the recording of as much ethnological information about the race as possible, and lobbying the government to protect Bass Strait muttonbird rookeries, which provided a livelihood for the half-caste population of the Islands.

The Society remained keenly interested in the question of acclimatisation of species and establishing new industries and its endeavours could be truly described as creating world-wide interest. When, for example, at the suggestion of Edwin Pears (a former school master at New Town and Royal Society member, then a barrister in Istanbul), the British Consul at Ankara wrote to the Society in 1874 to suggest the acclimatisation of the Angora goat, the members' keen discussion, which was reported in *Papers and Proceedings*, generated further correspondence on the subject from Santa Barbara, USA.

The membership that supported these activities fluctuated considerably. In 1848 membership increased from 81 to 123; and by 1854 a high point of 330 was reached — although only 240 were financial. As the effects of the economic depression of the 1850s became widespread, the local membership declined as many people left Tasmania for the more prosperous colony of Victoria, and some Corresponding Members joined the scientific societies which were being established in other colonies. Finance became a major problem and the publication of *Papers and Proceedings* was suspended, as were purchases for the library.

The person who, through good management, personal generosity, and his ability to obtain aid for the Society, was able to liquidate the Society's debt was Dr James Agnew (the successor as Secretary to Dr Milligan) who remained a leader in the Society's affairs until the 1890s. His name, together with that of Morton Allport and Francis Abbott, constantly appeared as a sponsor of new members, in vigorously mounted membership drives by the Society.

PAPERS AND PUBLISHING

After the last issue (in 1849) of the Tasmanian Society's *Tasmanian Journal*, the Royal Society's own transactions were published, providing the only vehicle within Australia for publishing scientific papers. Many writers became Corresponding Members for this opportunity to publish, and then became donors to the Museum because of their association with the Society.

At its meetings, members reported items of interest which ranged from remedies for blight in apple trees to the reproductive properties of Egyptian mummy wheat (grain from one ear of wheat yielded 872 ears according to Bishop Nixon). Similarly, the early papers were practical and designed to assist settlers in a new land: to improve current agricultural practices or suggest new industries. Such papers always stimulated the most vigorous discussion. Papers of a more scientific nature, for example new species of flora or fauna and geological discoveries, were welcomed because their publication enhanced the stature of the society. Gradually the Society became more discriminating about its publications: papers were only published if they contained original material and were not simply resumé of known knowledge; named specimens had to accompany any paper on new species, and papers had to be submitted to the Council in advance.

Baron von Mueller, a distinguished Corresponding Member, wrote of the "praiseworthy regularity and punctuality with which the Society issues its papers [which] affords the most favourable vehicle in Australia for the early recording of new observations".¹⁰ Outstanding local contributors included the Reverend J.E. Tenison-Woods, W. Legrand, W.F. Petterd, and R.M. Johnston for their

work on the marine, freshwater and fossil shells of the island. (Johnston, incidentally, was the most prolific contributor of papers to the Society in the nineteenth century.)

Morton Allport is one who exemplifies well the extent of the local, intercolonial and international scientific network. He joined the Royal Society in 1849, was a member of its Gardens Sub-Committee and a Vice-President from 1870–1878. In 1866 he was appointed one of the salmon commissioners. He was an organiser for the Great Exhibition in 1862, and a Commissioner for the Intercolonial Exhibition of Australia at Melbourne 1866–67. He was an agent for the ornithologist John Gould, and one of the earliest photographers in the colony. He was also responsible for the successful introduction of perch and tench into Tasmania. He corresponded with a number of scientific men in Europe, most notably with Dr Gunther of the British Museum, sending him specimens at his own expense. Allport received in return a great deal of valuable information which he passed on to the Society. A Fellow of the Linnaean and Zoological Societies and of the Royal Institute, he was also a Corresponding Member of the Anthropological Institute of Great Britain, a Life Member of the Entomological and Malacological Societies, a Foreign Member of the Royal Linnaean and Royal Botanical Societies of Belgium, and a Fellow of the Linnaean Society of New South Wales. His contribution to the Royal Society of Tasmania, until his early death at the age of 47, was a distinguished one.

THE LIBRARY

Provision was made in the original rules of the Society for a library and, initially, a library of general literature, to which the public would have access, as it did to the Society's Gardens and Museum, was envisaged. When a separate public library was established in 1849 it was decided not to compete in establishing a general collection but that the Royal Society would concentrate on building a major scientific collection to which the public would have access.

From the first distribution of complimentary copies of the *Papers and Proceedings* in 1849, an international network of publications exchange developed which immeasurably enhanced the Library. By the 1870s the Library was described by one scientific writer (and traveller) as "the best and most extensive collection of scientific works in the Australian colonies";¹¹ and the Society was exchanging publications worldwide with universities, State and Federal government departments and independent organisations. When one considers factors such as distance, time, cost and risk of loss, the achievement is enormous. (The quality of the book and journal collection is perhaps the greatest single achievement of the 150-year history of the Society.)

THE GARDENS

In the minds of the public, however, in the early days, it was the Gardens and the Museum which provided a public face for the Society. It was, after all, for the administration of the Gardens that the Society had been set up. At the outset the fourteen acres of Colonial Gardens for which the Society received a £400 government grant, comprised mainly fruit trees and better known European plants and shrubs, with only a small collection of indigenous plants and rarer European



PLATE 2

The Royal Society's Gardens, Hobart, with Government House in the background. Charles Abbott, photographer, 1858. (W.L. Crowther Library, State Library of Tasmania, Hobart.)

varieties. The value of belonging to the Society for many, however, was access to these Gardens (plus free plants and cuttings) and the right to take visitors there. But from the first year of its existence the Society began to move towards a position where it administered the Gardens in the interests of the public, its own members enjoying no special privileges. While the sale of plants provided a welcome income, the Society was anxious not to compete unfairly with the professional nurserymen of the town by the sale of popular plants at cheaper prices. From 1845, an intercolonial and international exchange system of plants and seeds was set up and there was an increasing emphasis on developing the indigenous, exotic, and acclimatised plant collections. Common fruits and vegetables were only cultivated to demonstrate some new or important characteristic of the plants, or application of their products.

Judging from the Society's reports, however, it valued the Gardens for their recreational and educational qualities and their beneficial effect on the community's health and morals, as much as for their botanical significance. Visitor numbers rose from 2287 in 1847 to 15 710 in 1855, the weekly performances of the band of the 99th Regiment contributing to the Gardens' popularity.

The administration and development of the Gardens remained the pre-eminent activity of the Society in some members' opinion. In its endeavours the Society was well served by the two superintendents of the early period: F.W. Newman until 1859 and then Francis Abbott. The latter managed — despite an increasingly inadequate grant — to raise plants for sale; conduct plant and seed exchanges with individuals and institutions worldwide; solicit and acknowledge donations; continue to extend the area of gardens under cultivation to 25 acres (approx. 10 ha) by 1877, with in excess of 7000 varieties of plants (using a staff largely comprising inexperienced prison labour); and also cope with visitors who in that year (1877) numbered nearly 56 000.

THE MUSEUM

As with the Gardens, an increasing number of people visited the Society's Museum: 683 in 1853 compared with 5680 five years later. Thomas Roblin was appointed Curator in 1862 and this "faithful, zealous and efficient officer"¹² laboured to build up the collection.

The government grant was spent on salaries, administration, rent and maintenance of the building — but not on the collection itself. Even more than the partly self-supporting Gardens (with plant sales) and the library (with its publication exchanges) the Museum was dependent on donations, both from resident and Corresponding Members, local non-members and individuals and institutions beyond the colony. The exchange of duplicate specimens was the only other way the museum could build up its collection. (In return for one Tasmanian Tiger the Australian Museum in Sydney gave the Society 78 specimens of mammals, birds and reptiles so the system could be advantageous.)

From its earliest days the Society was keen to provide a permanent home for its growing collection. When visitor numbers dropped from over 6000 in 1859 to 427 the following year, the major reason was said to be the unattractive overcrowding of exhibits. The Council of the Society sought from the government a central site and a

special grant for a building "becoming in architectural character and ample enough for the demands of a century or two".¹³ Joseph Milligan, the first Secretary of the Society, was outspoken where others might have compromised and finally the government gave the present Museum site. Henry Hunter's architectural design was chosen in a public competition and the lowest building tender (offered by Messrs Seabrook and Son) was accepted. The foundation stone was laid in August 1861 and the building was completed the following year — an art exhibition being held to provide the fittings for the Museum. Individual members assisted in organising the new Museum. Charles Gould, Government geologist, arranged the geological section, adding to it a collection he had received from Sir Roderick Murchison in England.

Visitor numbers did not really climb until 1877 when the Museum was opened on Sundays. Within a year attendance on Sundays during one month exceeded that on weekdays for the same period and in 1878 almost half of the 33 466 visitors came on Sundays. There was little overt protest at Sunday opening although at least one person, James "Philosopher" Smith, declined honorary membership of the Society (offered in recognition of his contribution to the mining industry) because the Society opened its Museum on Sundays.

During 1885, there was a marked increase in donations to the Museum, probably due to the activities of the new curator Alexander Morton. Throughout the year the Council made strong representations to the government for increased finance for the Museum, and for extensions to be built. But although the Society worked within a network of influence in many things, it could not persuade the government to endow the Museum and the Gardens more adequately.

CONCLUSION

While making rules and regulation for managing the Gardens, the Council found they had not power to enforce them because the grounds were not vested in the Society. It had originally been allowed to take up the land but had no title to it. Secondly, the Society wanted to secure the small area adjacent to the Museum for extensions and was concerned that it might be developed commercially. The Council wrote



PLATE 3

The Royal Society's new Museum, corner of Argyle and Macquarie Streets, Hobart. Samuel Clifford, photographer, 1862. (W.L. Crowther Library, State Library of Tasmania, Hobart.)

to the Premier to request the vesting of the site of the Museum and Gardens in the Trustees of the Royal Society. This had been mooted when the Museum was built, and favourably considered by the Government, but not acted upon.

After some consideration of the need for regular and permanent financial support, legal ownership, and the desirability of giving the two institutions a "national" character, the Council drew up a draft proposal for the government to endow and incorporate the Museum and Gardens. It was to be totally accepted by Parliament or the Bill would be withdrawn. The draft was based on the New South Wales Museum Act.

It was accepted, and in 1886, a new phase of the Society's existence began. With the transfer of the Gardens and the Museum, the Society's role in the community was less apparent. But its scientific contacts with other countries were maintained and strengthened through its Papers and Proceedings, and its role as a scientific society, disseminating original scientific data, increased under the guidance of Dr Agnew and Alexander Morton, who were to serve the Society for many more years.

The year 1886 is an appropriate one at which to finish, for it not only signified the end of an era in Tasmania, but the beginning of another for Australian science. Professor A. Liversidge, President of the Royal Society of New South Wales, established (in that year) a federal association of the thirty-eight scientific bodies, which existed in Australasia: the Australasian Association for the Advancement of Science — the first national scientific body in Australia. Its first President, H.C.C. Russell, said: "This association stands as a protest against the short-sighted and utilitarian policy of those who would cultivate only what they characteristically call the bread and butter sciences. Our purpose is the advancement of all the sciences."¹⁴ Freed of two responsibilities which had been the source of much financial and managerial worry, the Royal Society of Tasmania was in a stronger position to respond to this challenge in the following years.

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